Cost Effective ToF Lidar Using GaN Devices

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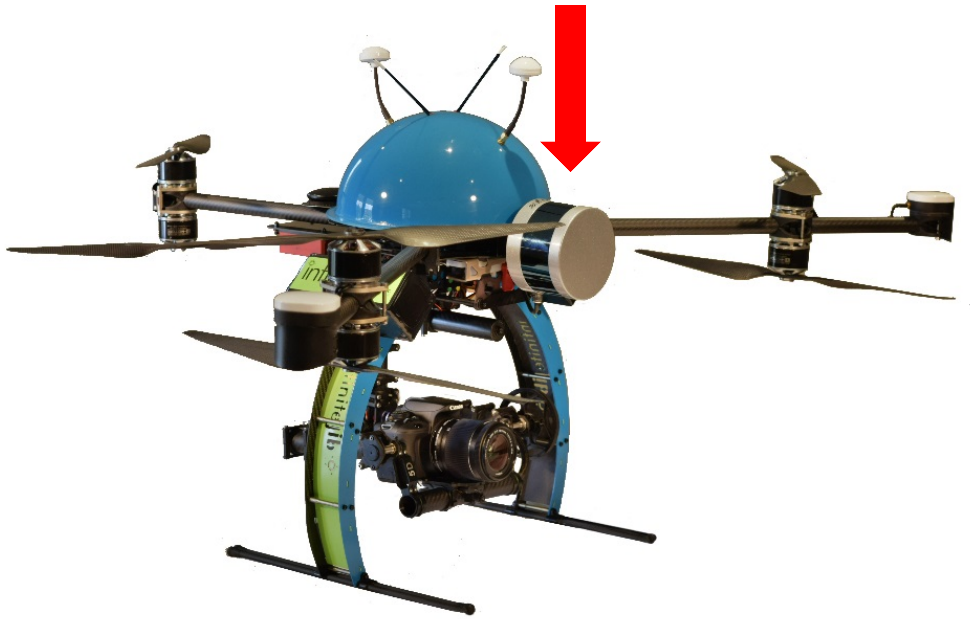
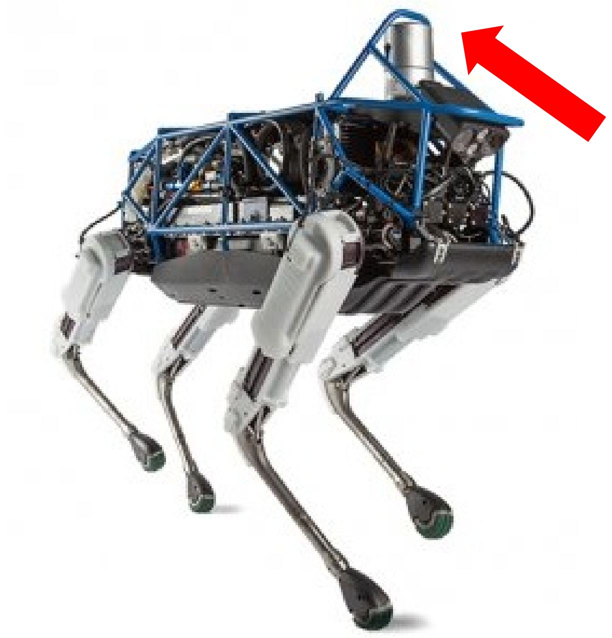
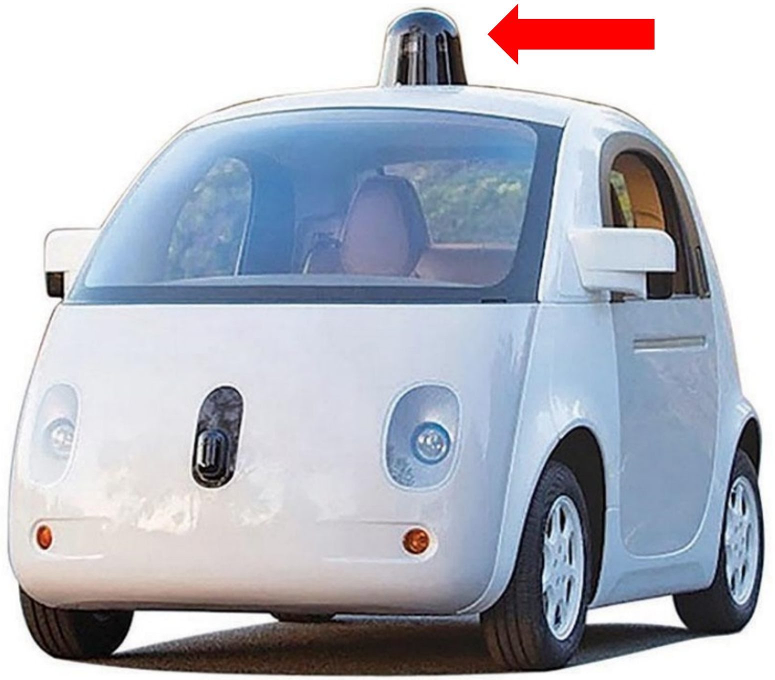
Topics

- What is lidar?
- Basic lidar laser drivers
- Why eGaN® FETs?
- Inductance
- Layout
- Performance examples
- Conclusion – Upcoming trends

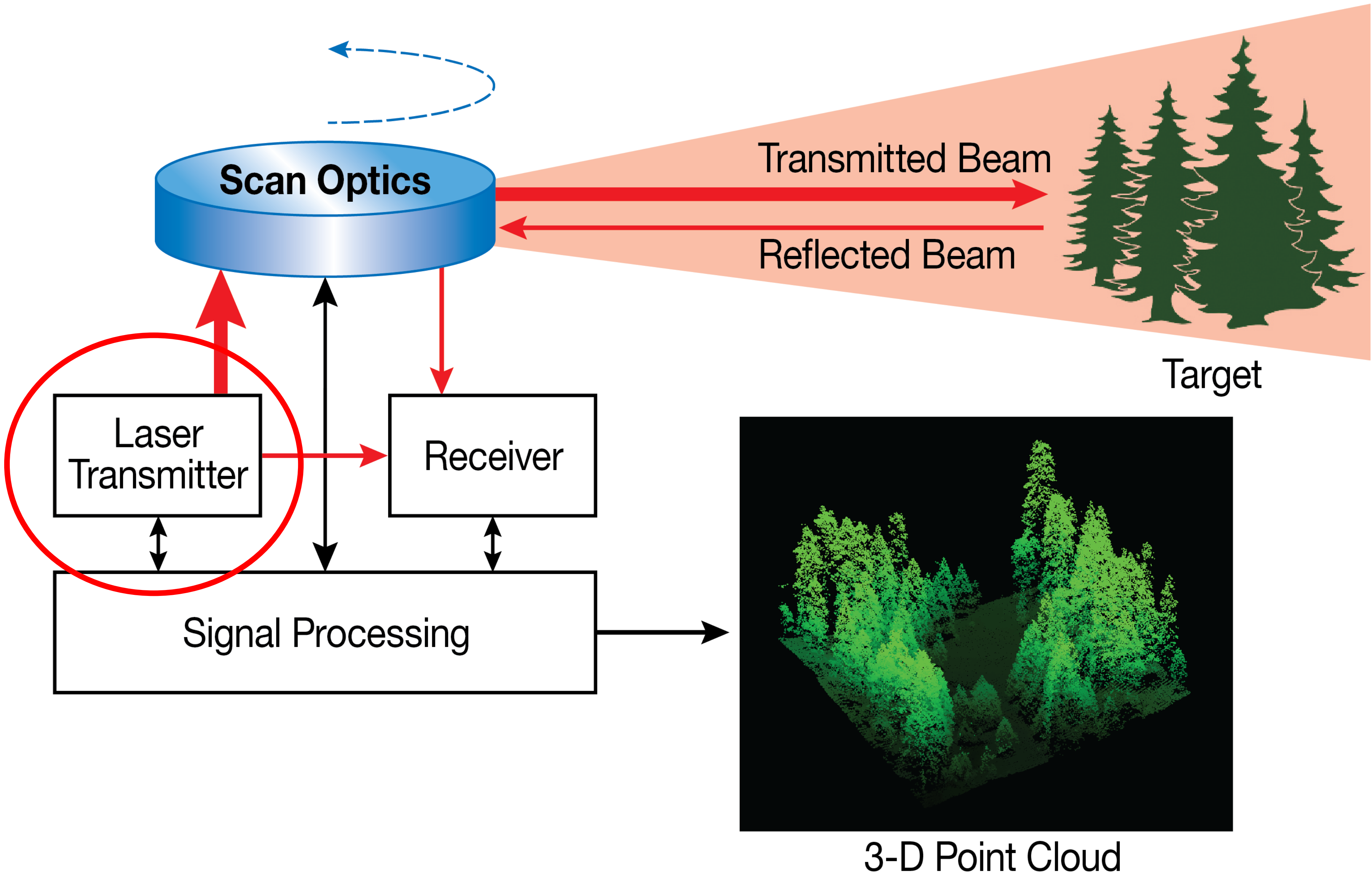
Lidar for Autonomous Vehicles







What is Lidar?

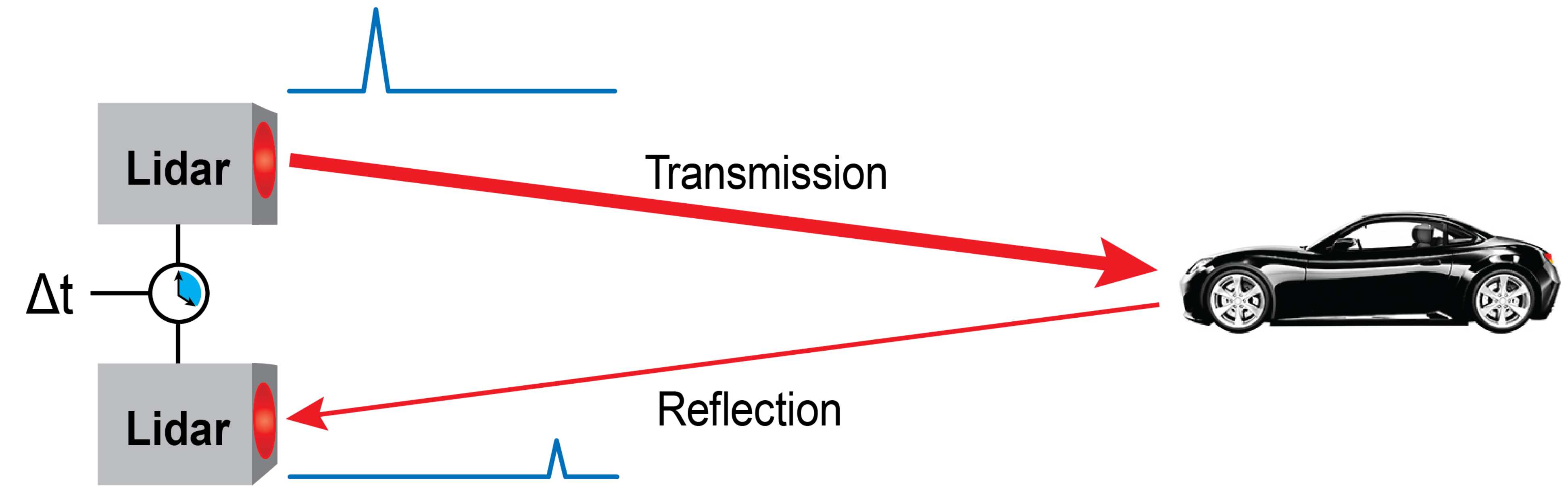


Source of 3-D point cloud image: http://ucanr.edu/blogs/green//blogfiles/11605_original.png

Types of Lidar

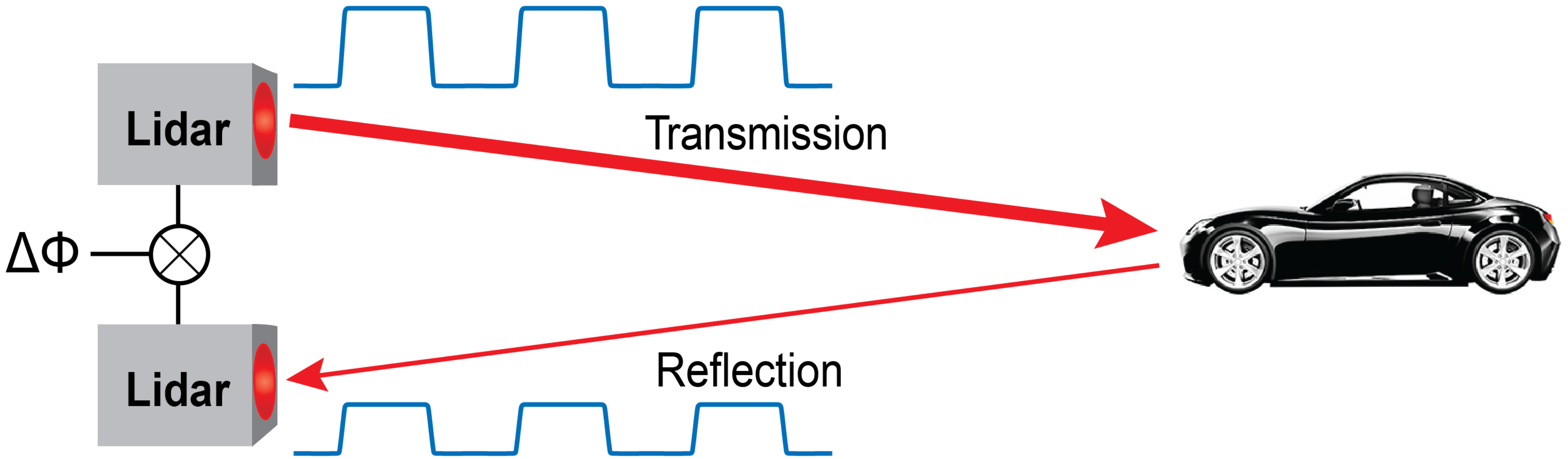
- Time of flight (ToF) for distance measurement
- Doppler
- Spectroscopic
- Multispectral
- Polarized
- …

Direct vs. Indirect ToF



Direct (DToF)

Measure time difference between TX and RX pulse

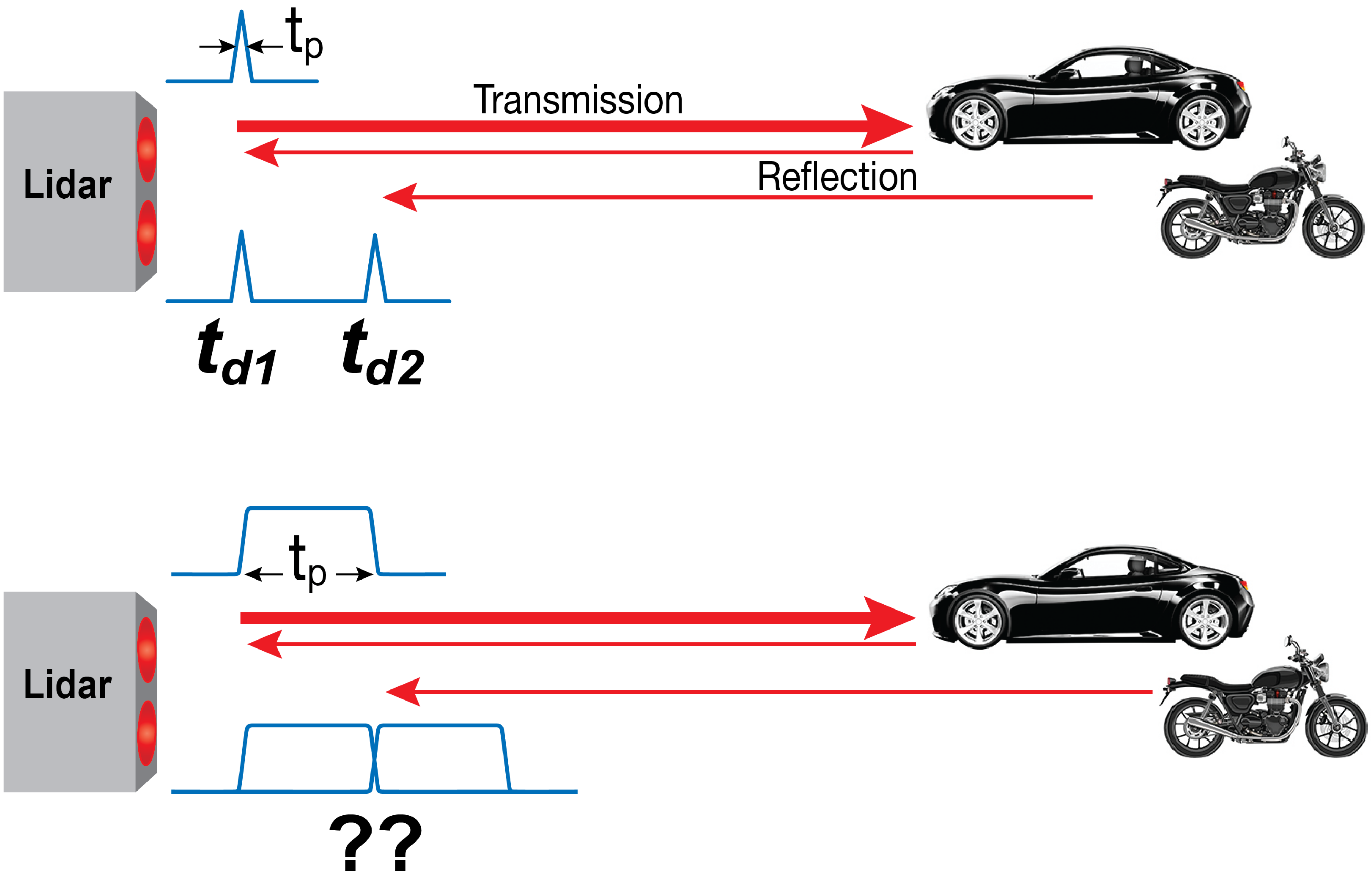


Indirect (IToF)

Measure phase difference between TX and RX envelope

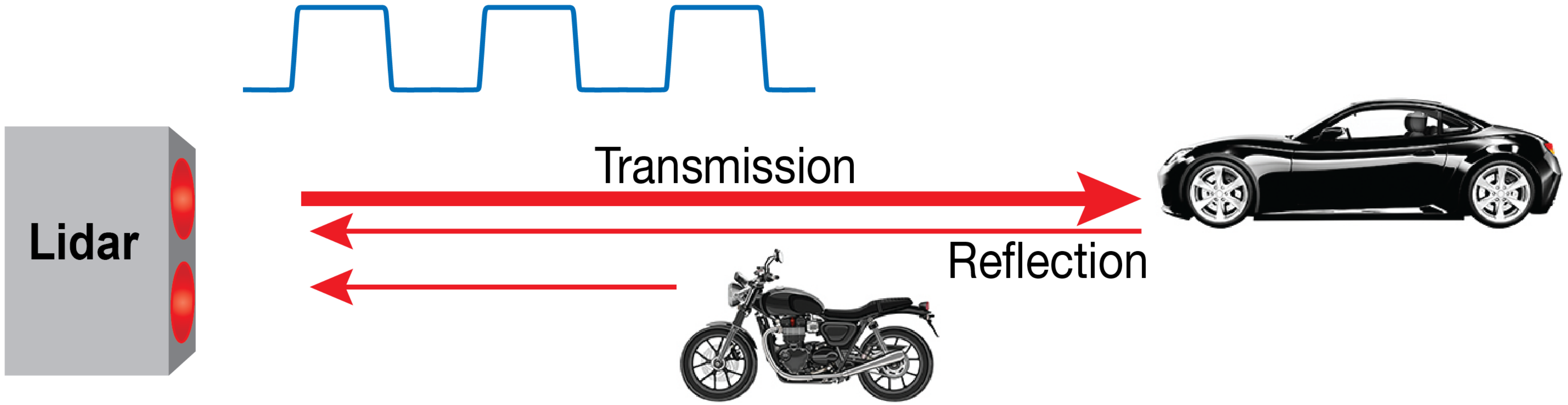
Importance of Pulse Shape (Direct)

$$d = \frac{c\, t_d}{2}$$



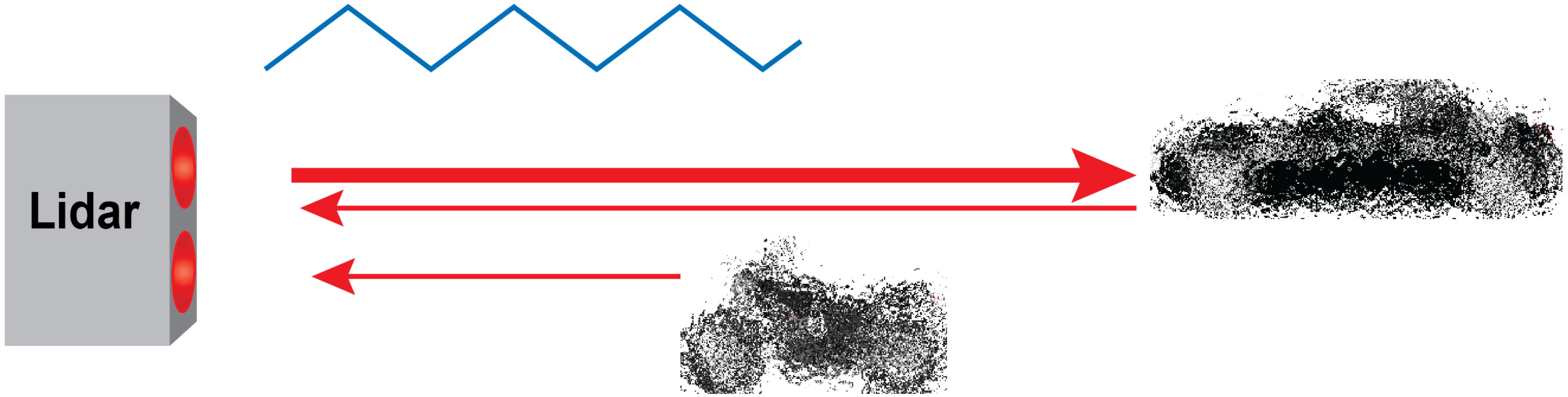
Shorter pulse = better resolution

Importance of Pulse Shape (Indirect)



Fast transition

- Linear phase and time response
- Low cost CMOS detector
- Direct ToF readout



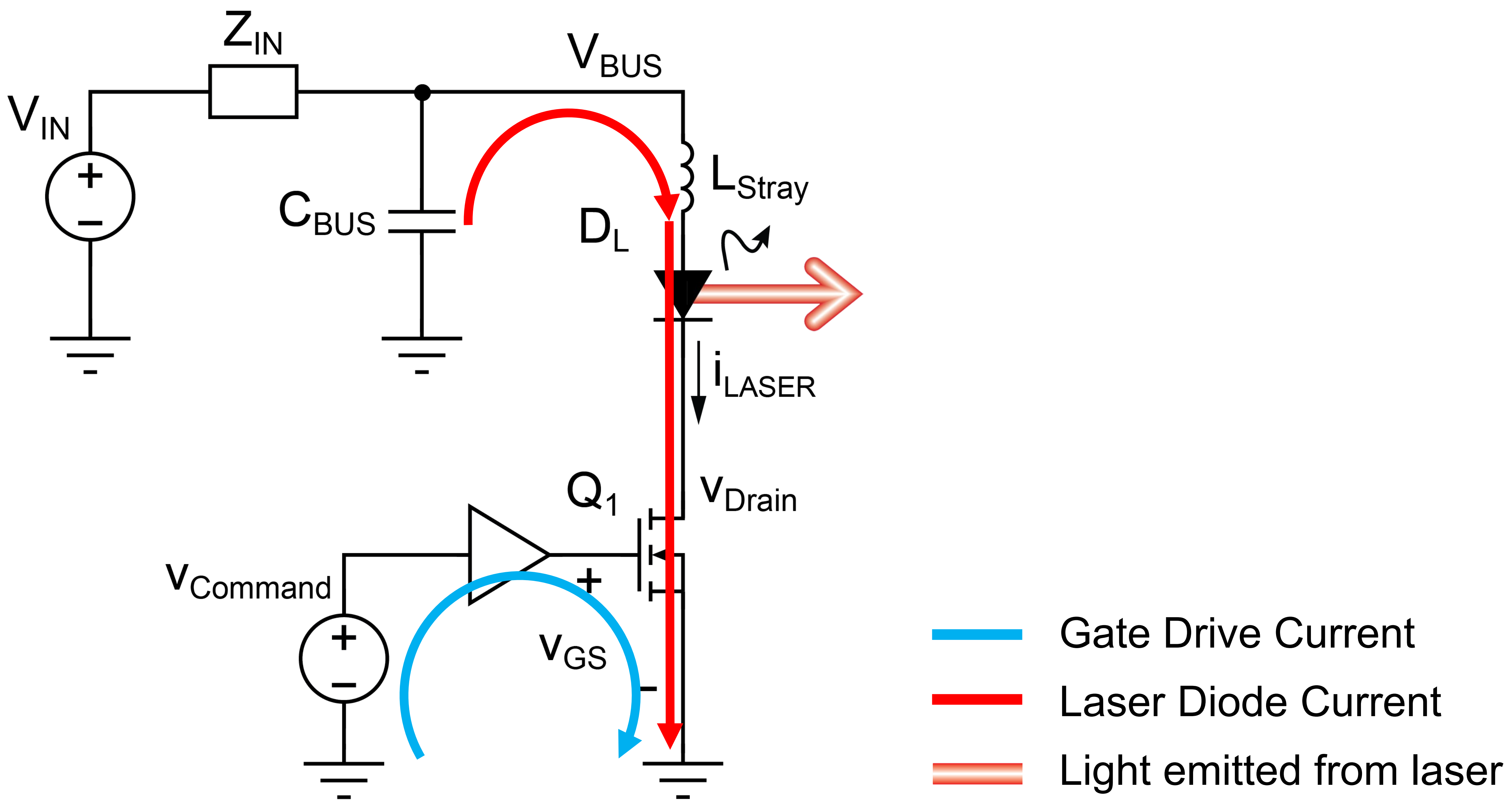
Slow transition

- Nonlinear response
- Computation required

Amplitude (Both)

- Higher pulse amplitude = increased range
- Pulse amplitude limits:
  - Laser thermal limitations
  - Eye safety limits

Laser Transmitter Circuit



Pulse Width and Amplitude

Long-Range Lidar

Target: Up to 300 m

Pulse: 5 ns – 50 ns

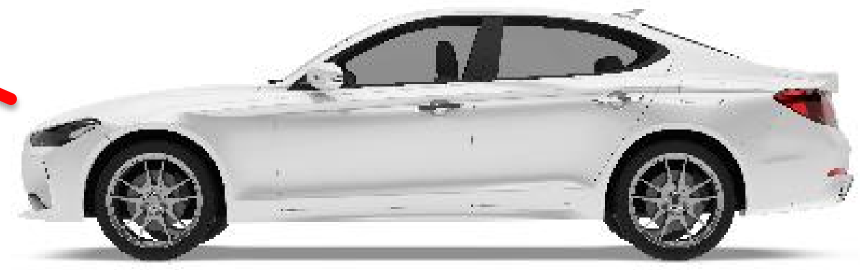
50 A – 500 A

Short-Range Lidar

Target: Up to 10 m

Pulse: 0.5 ns – 5ns

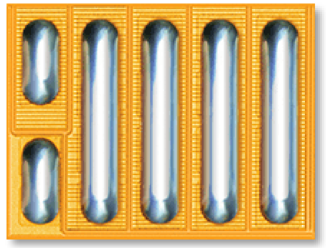
5 A – 50 A



Why GaN?

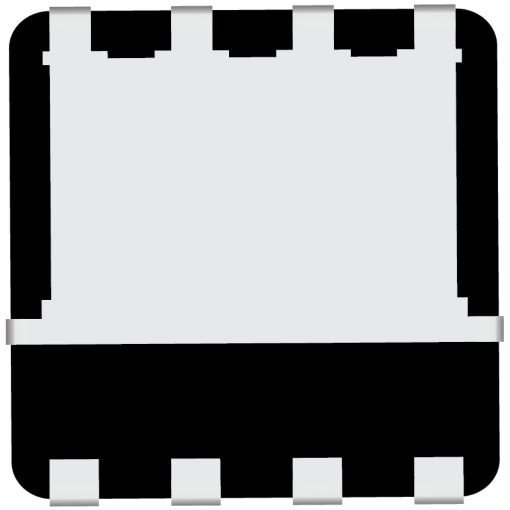
Parameter	EPC2212	Best in Class
Technology	**GaN FET**	Si MOSFET
$V_{DS,max}$ (V)	**100**	100
$R_{DS(on)}$ (mΩ)	**14**	21
$I_{pulse,max}$ (A) @ 4.5 V	**75**	80
Q_{Gtot} (nC)	**3.2**	7.6
R_{gate} (W)	**0.4**	1.0
$R_{gate} \cdot Q_{Gtot}$ (Ω • nC)	**1.3**	7.6
L_{gate} (nH)	**0.2**	3.0
L_{source} (nH)	**0.1**	0.3
L_{drain} (nH)	**0.1**	1.0
Package (mm x mm)	**LGA 2.1 x 1.6**	DFN 3.3 x 3.3
AEC-Q101	**YES**	NO

GaN FET

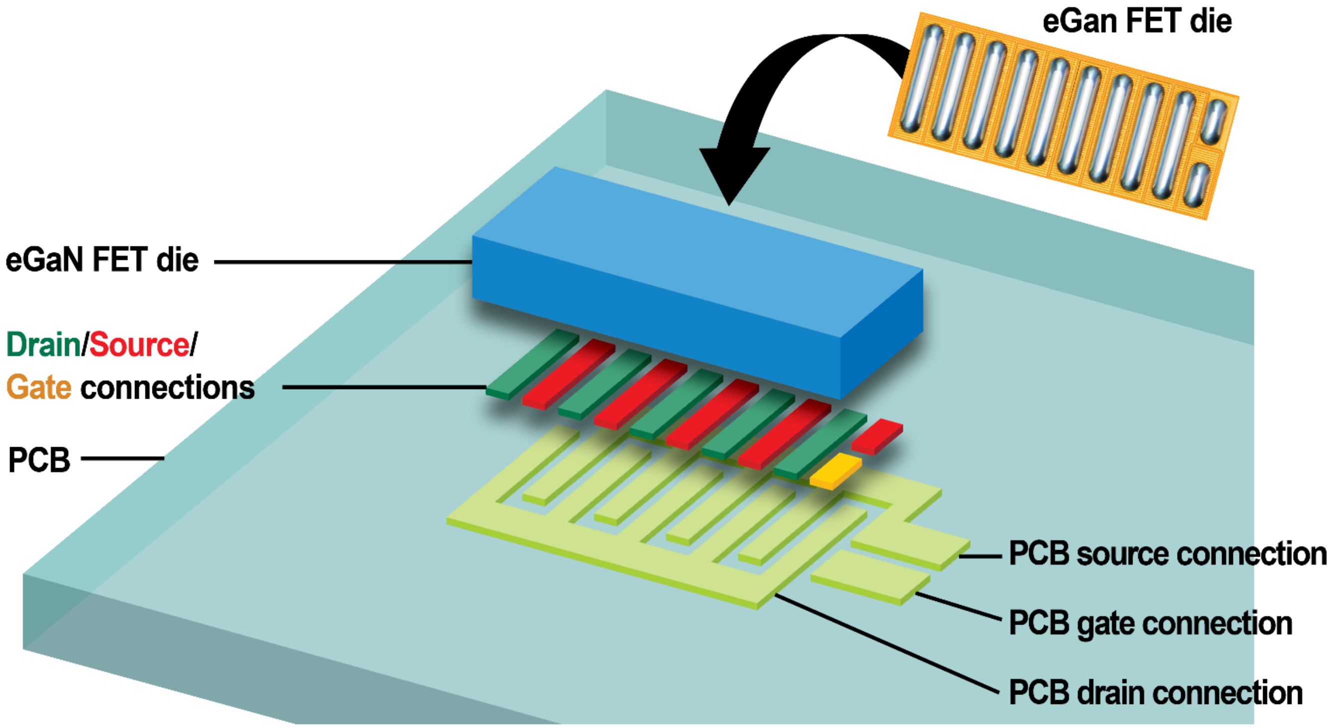


EPC2212

Si MOSFET

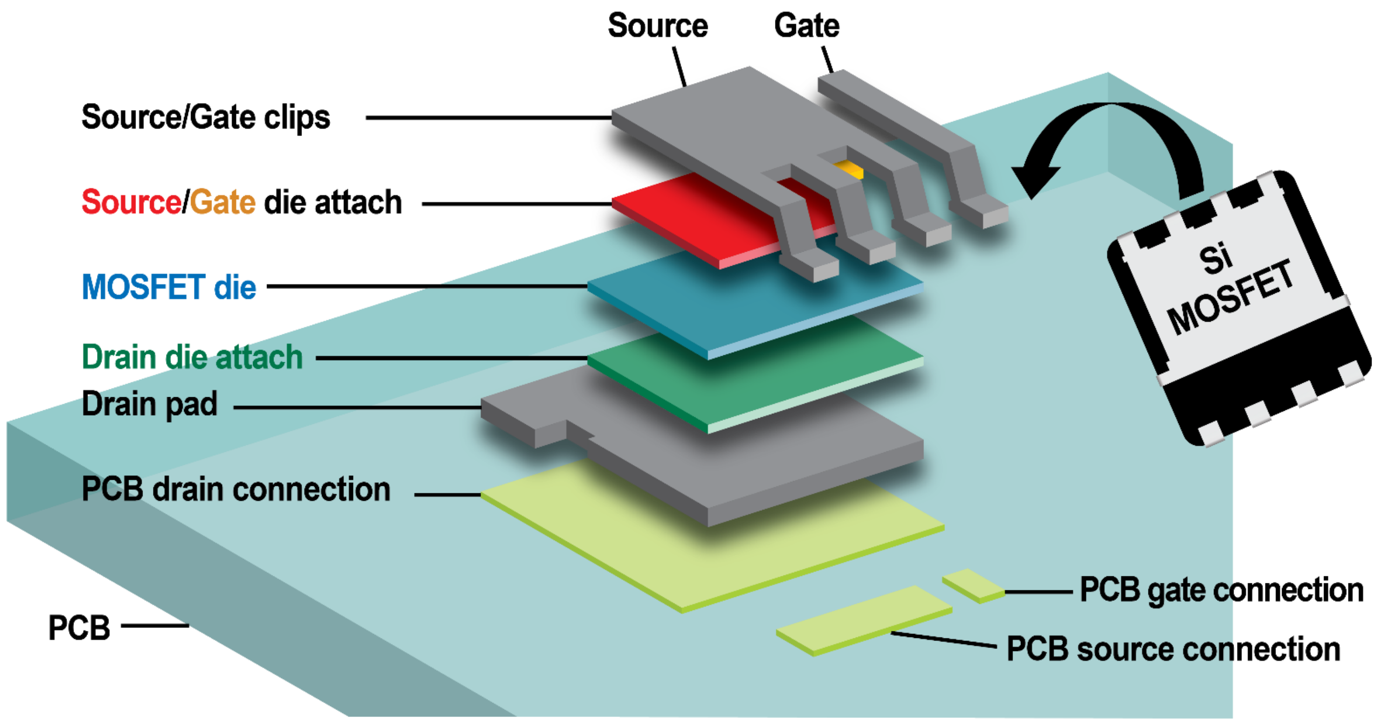


Why GaN?



Simple chip-scale package

- Low inductance
- Small size

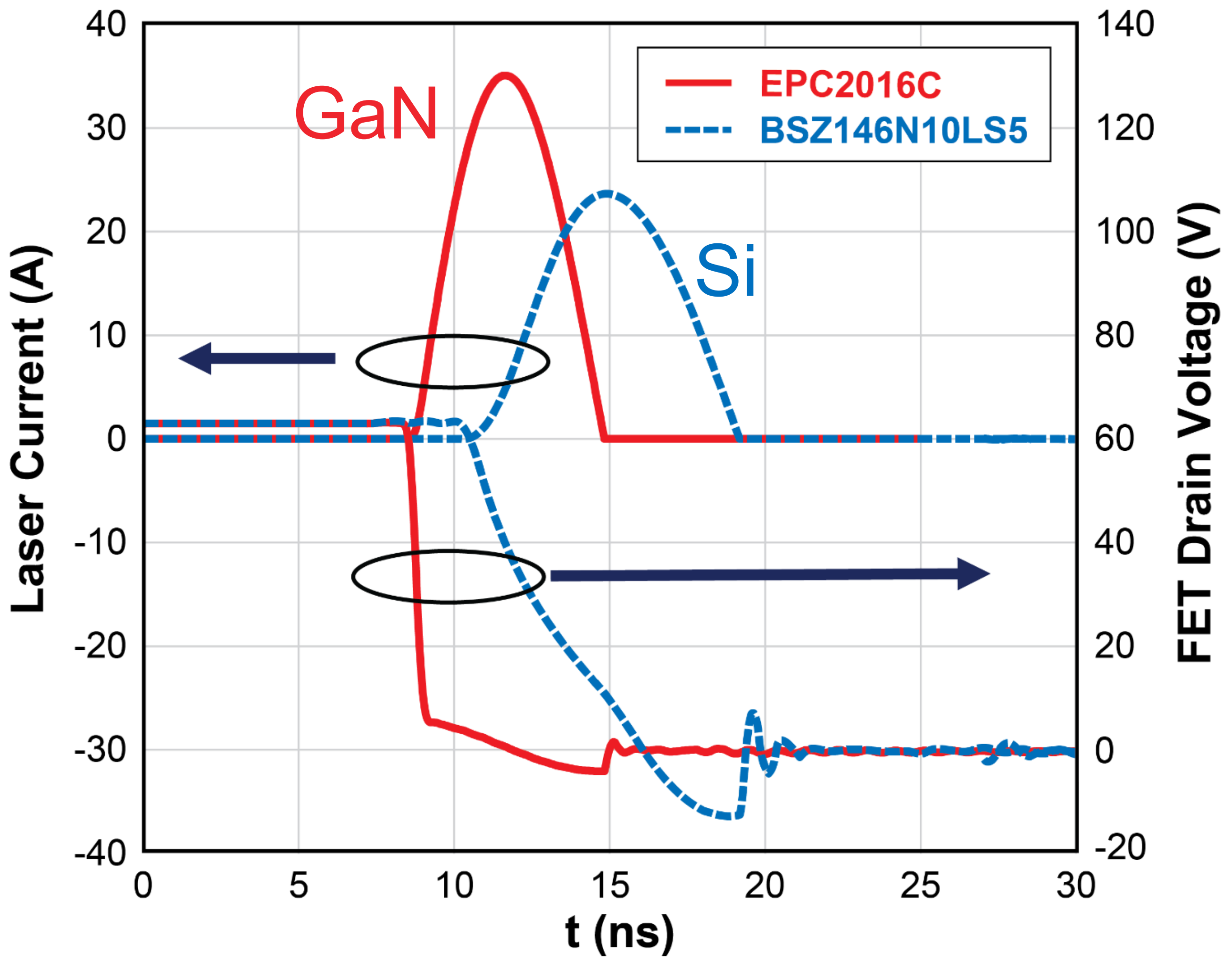


Complex package

- High inductance
- Large size

Simulated Performance

I_{DLpk} = 36 A, L_{LASER} = 3 nH, t_w = 4.0 ns → V_{IN} = 69.0 V, C_1 = 1.22 nF

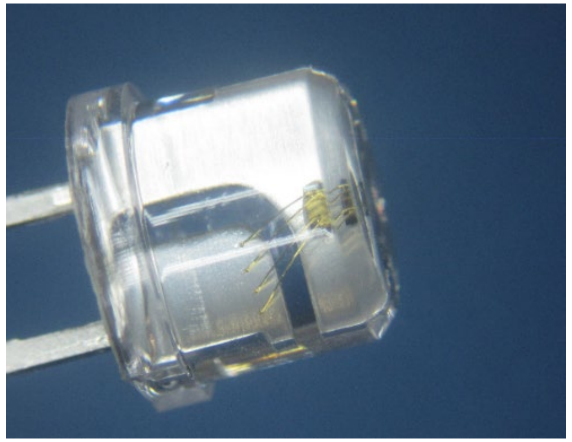


FET	Tech	I_{DLpk} (A)	t_w (ns)
Ideal Switch	Ideal	36.0	4.00
EPC2016C	GaN	35.1	4.02
Best in Class	Si	23.7	5.21

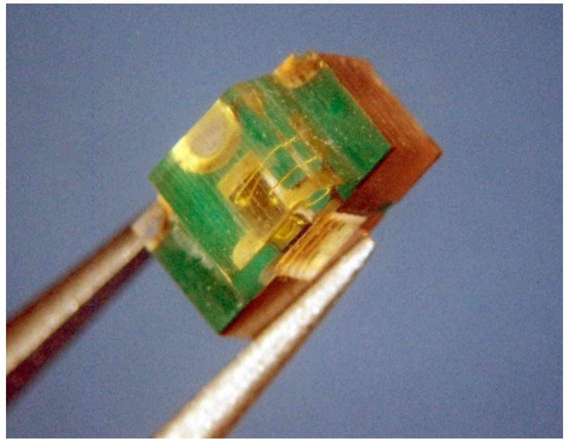
- **Customer demands are for even higher current and shorter pulses**
- ***Silicon has already hit the limit!***

Laser Diodes

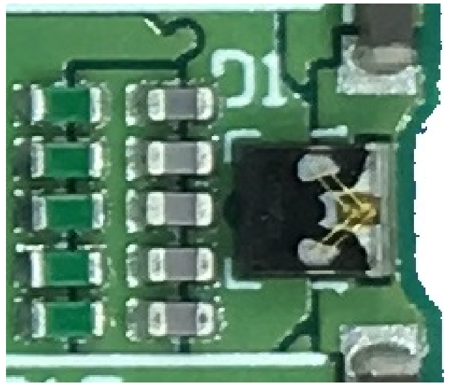
SPL PL90_3 (c. 2007)



TPGAD1S09H (c. 2013)



SPL S1L90A_3 A01 (2019)



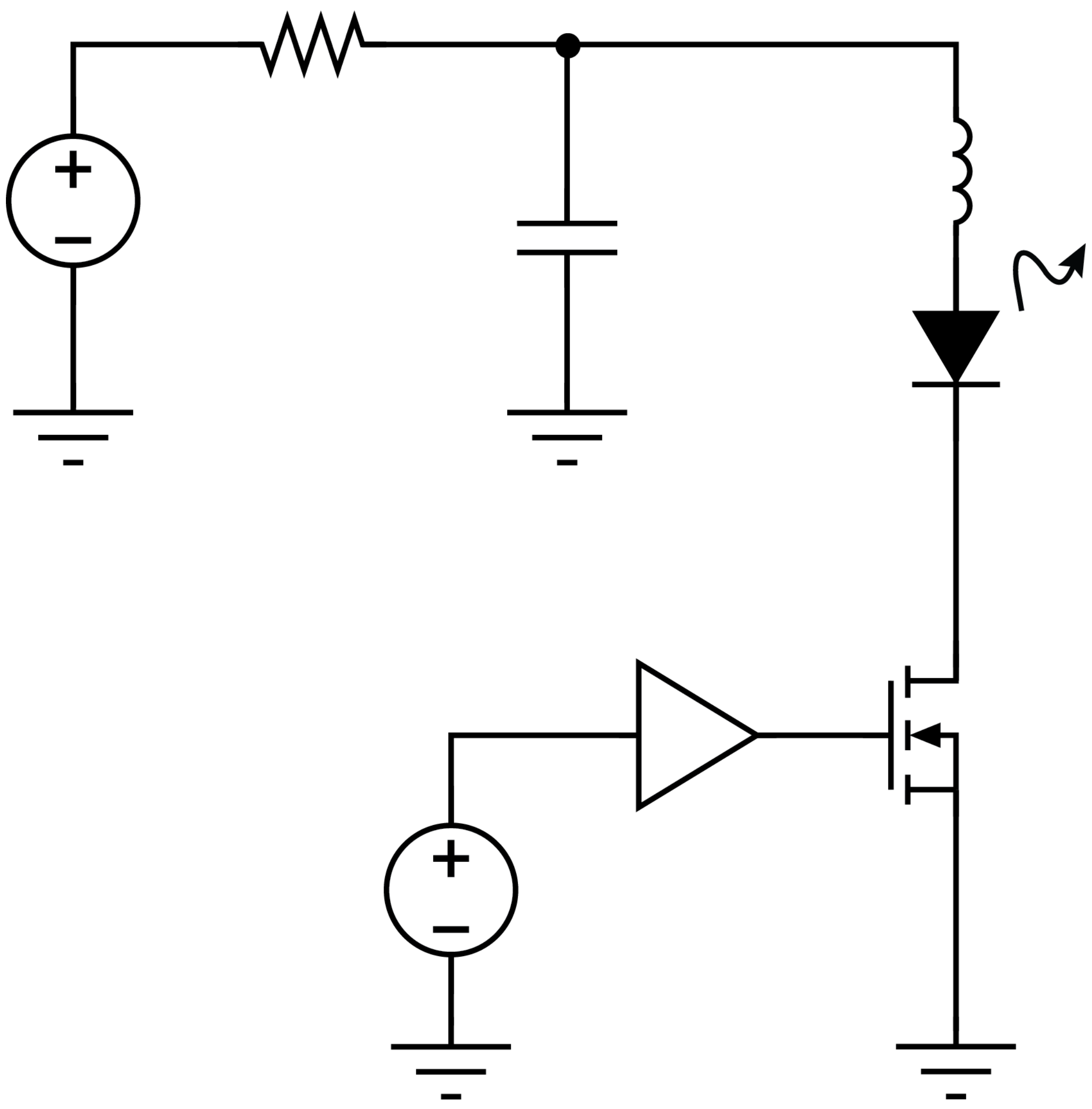
Part No.	λ (nm)	I_{Fmax} (A)	V_{Fmax} (V)	$P_{opt,max}$ (W)	Package	L (nH)
SPL PL90_3	905	30	9	75	Through hole	5
TPGAD1S09H	905	30	12.5	75	Surface mount	1
SPL S1L90A_3 A01	905	40	11	125	Surface mount	~ **0.5**

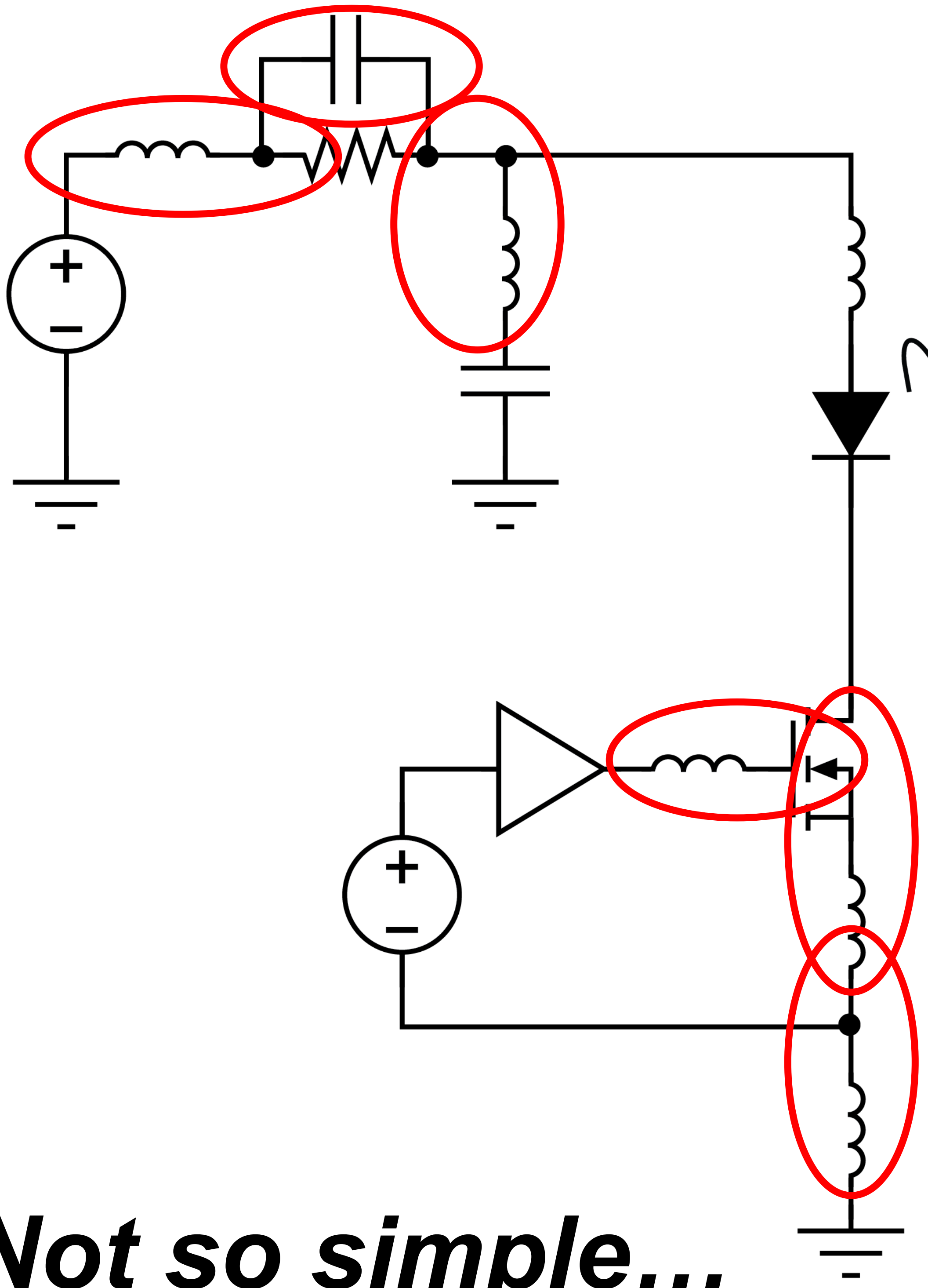
Design and Layout

Minimize:

- Power loop inductance
- Gate loop impedance
- Mutual inductance

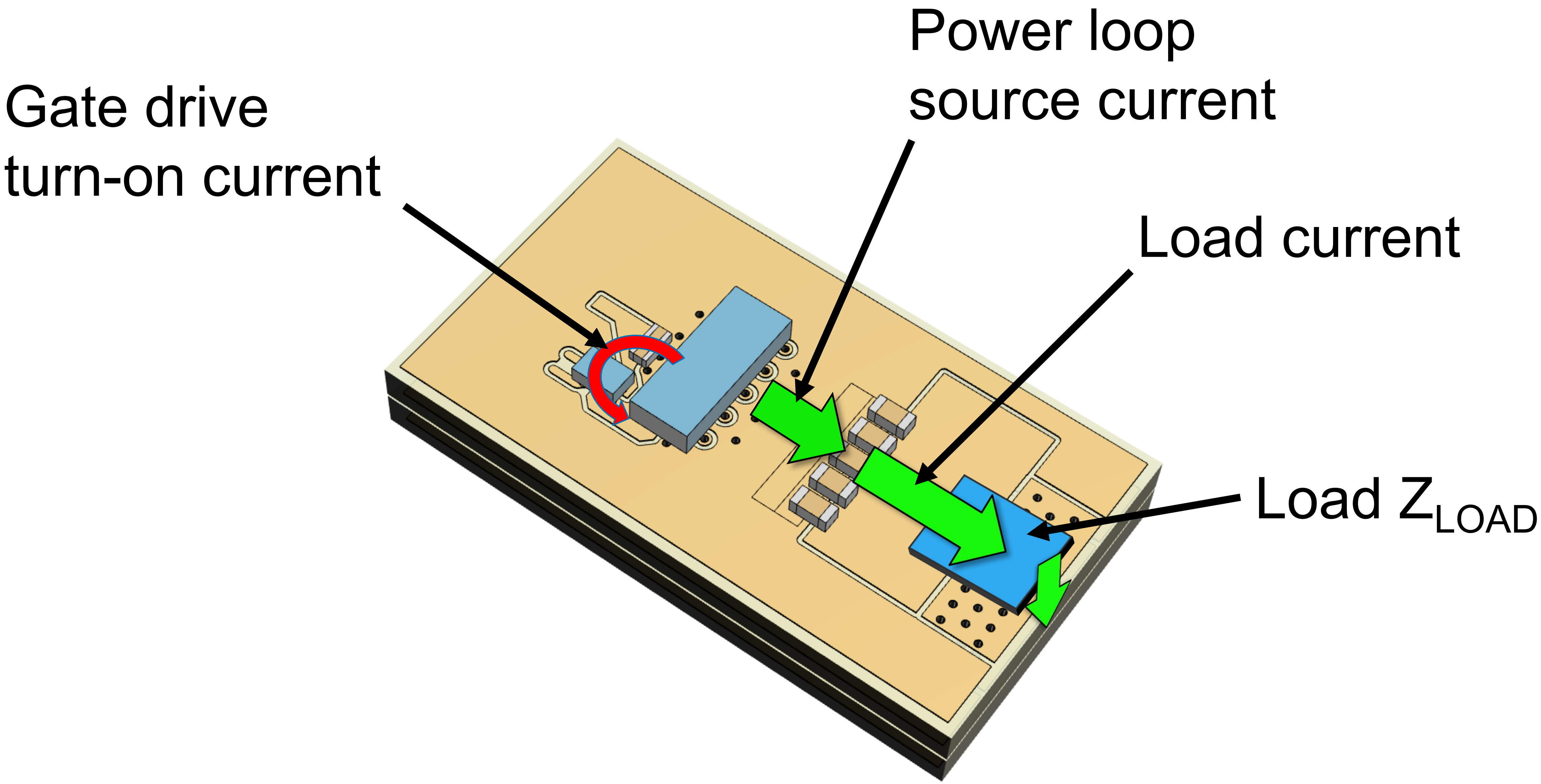
Simple?



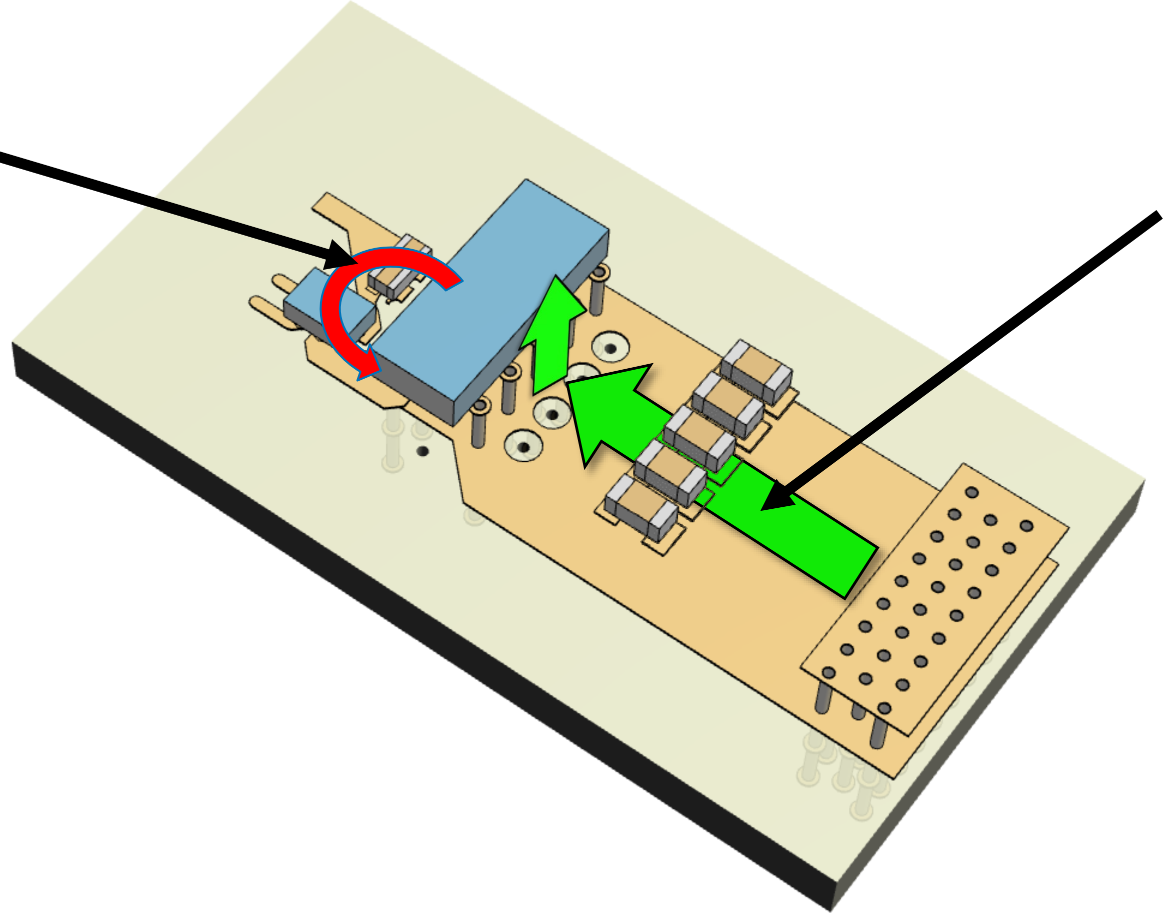


Not so simple…

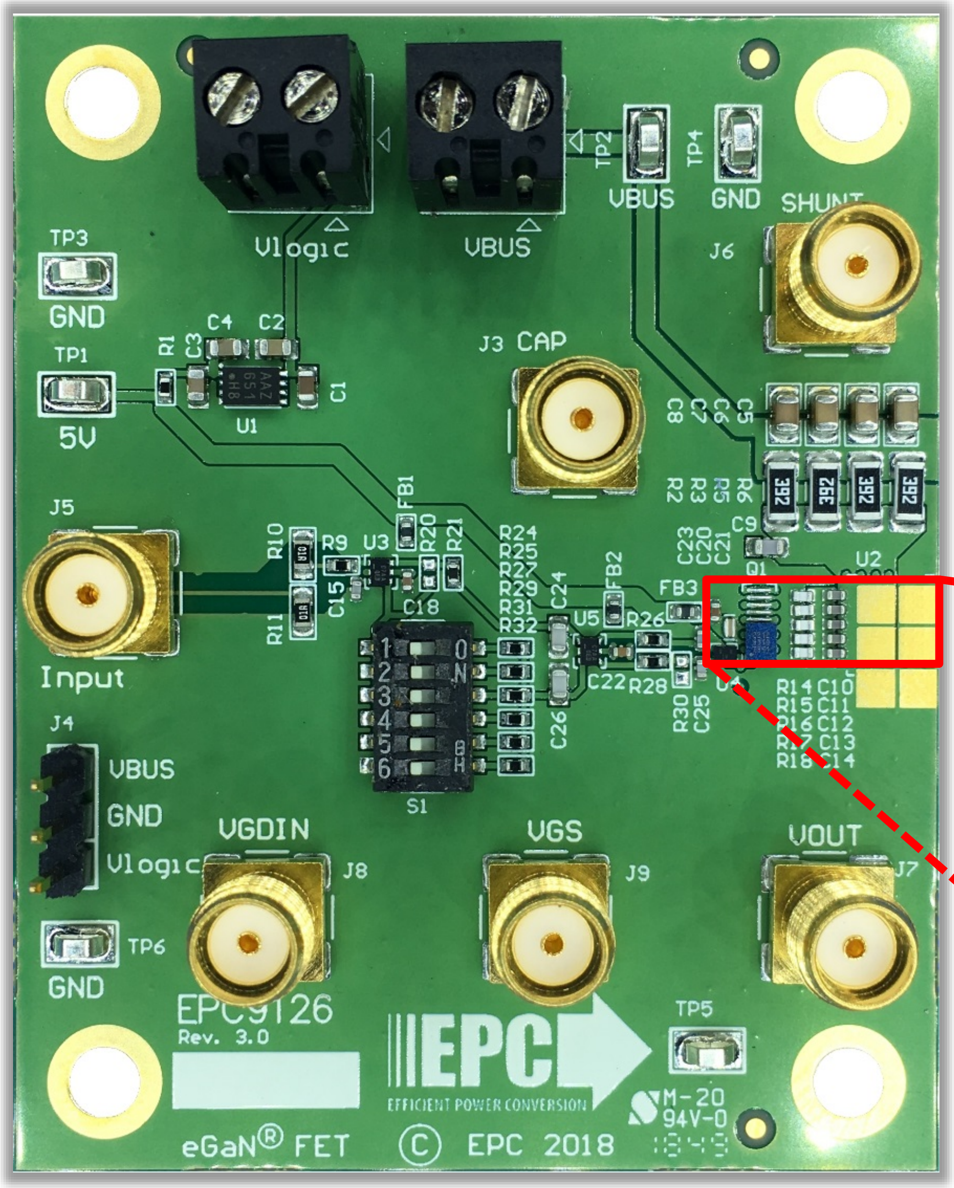
Layer 1 (top): Source Current



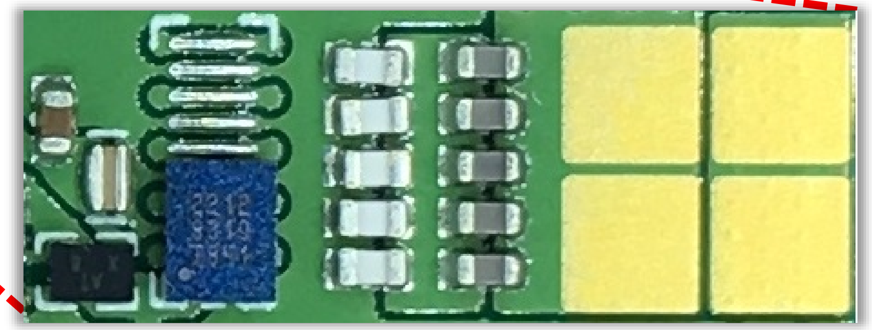
Layer 2: Drain Current



EPC9126 Laser Driver (DToF)



- 75 A or 150 A FET
- Includes built in probes
- Fits many lasers



5 mm

15 mm

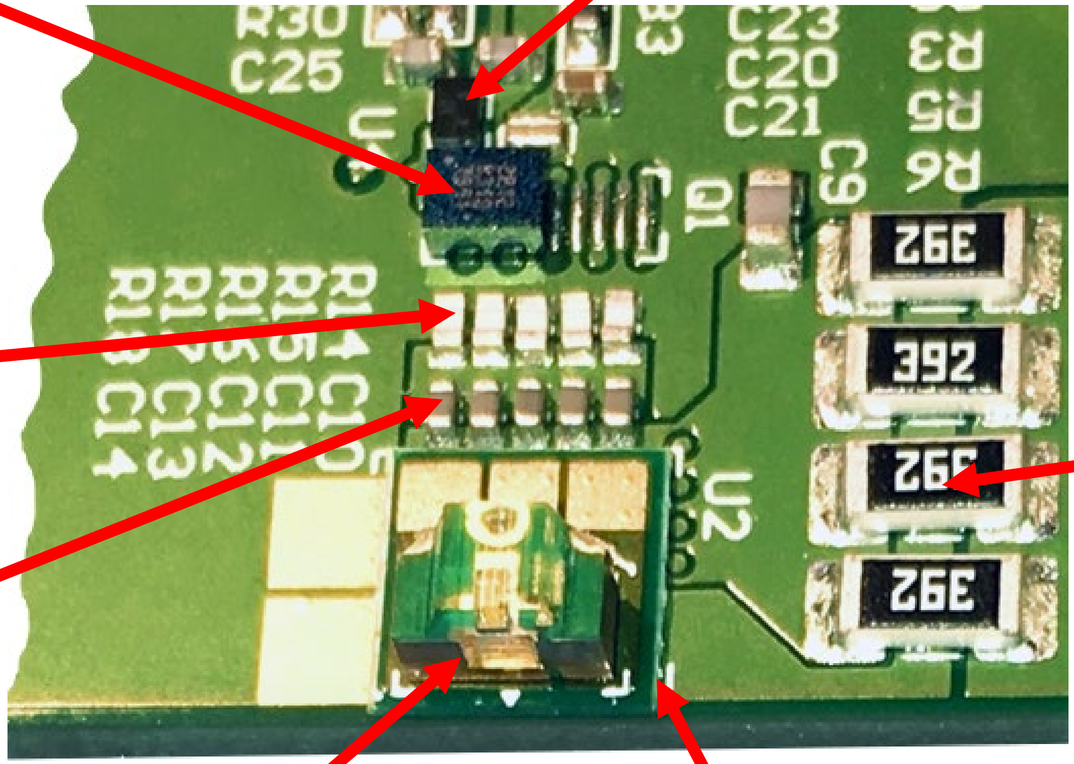
EPC9126 Laser Driver (DToF)

EPC2212 (AEC-Q101) or EPC2001C

LMG1020 Gate driver

Current shunt

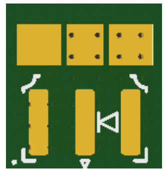
Discharge capacitors



Recharging resistors

Laser diode or load

EPC9989 interposer



EPC9989 Interposer

OSRAM PLPVQ 940A

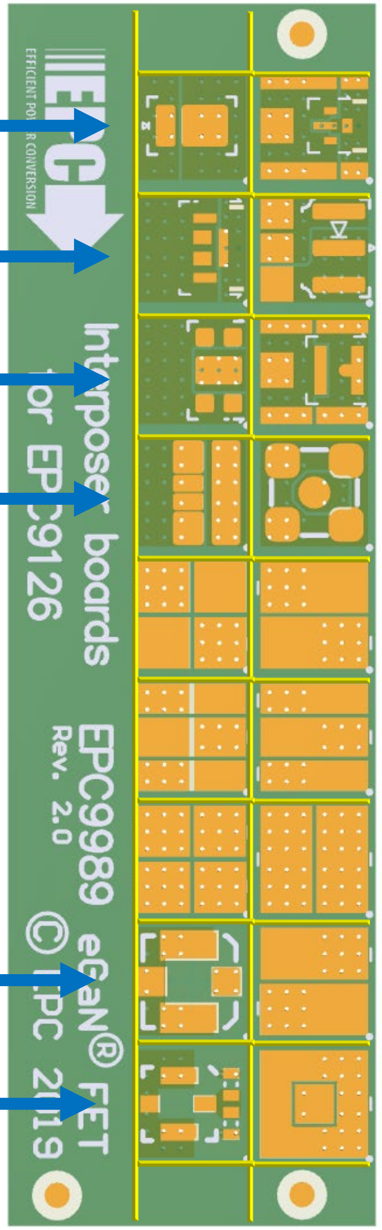
OSRAM SPL S4L90A_3 A01

Excelitas TPGAD1S11A-4A TPGAD1S09A-4C

Hamamatsu L15326-01（230 µm×4 ch）

U.FL Amphenol A-1JB

X.FL Hirose X.FL-R-SMT-1(02)



OSRAM SPL S1L90A_3 A01

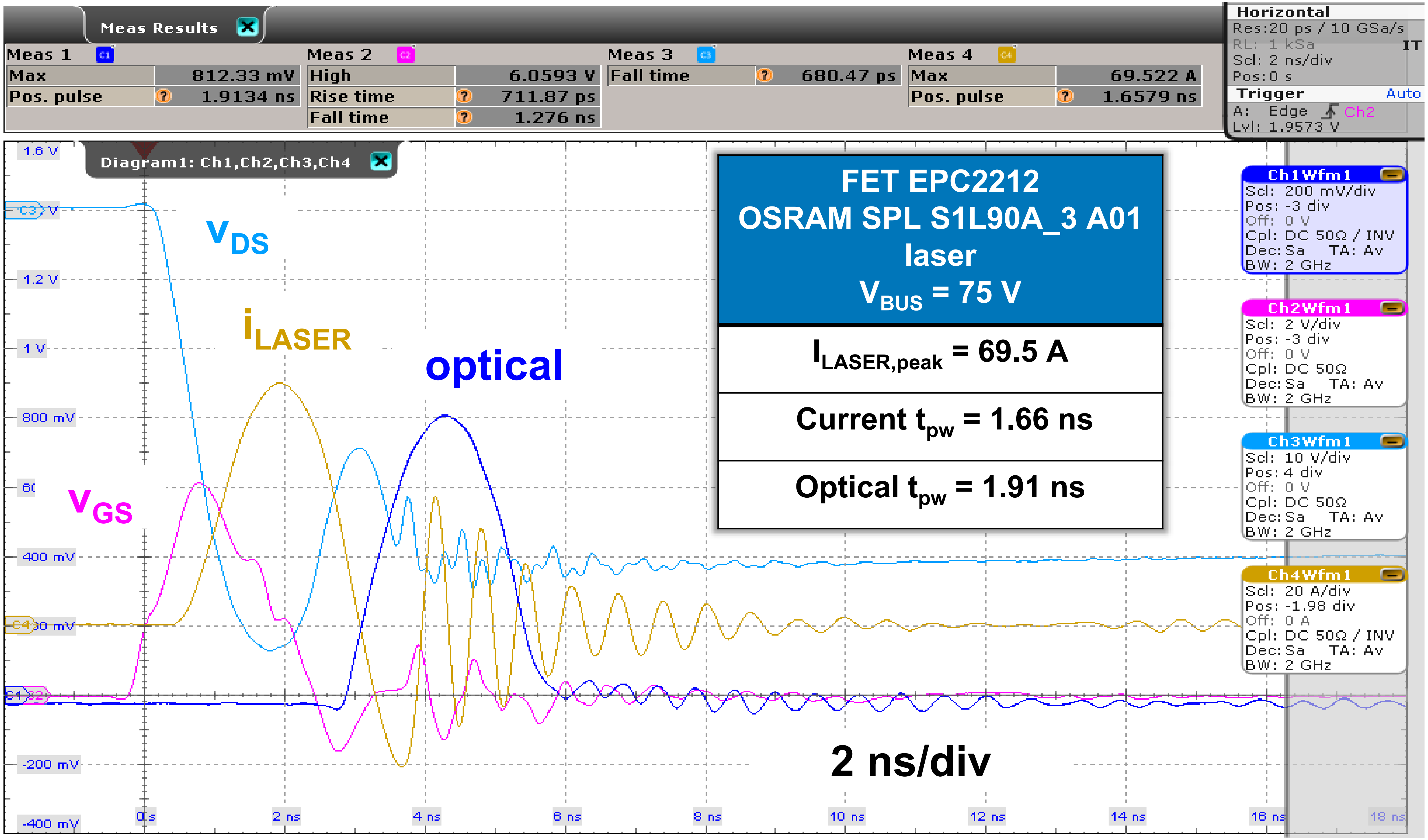
Excelitas TPGAD1S09H TPGAD1S03H

Hamamatsu L14774-01（230 µm） L14829-01（360 µm）

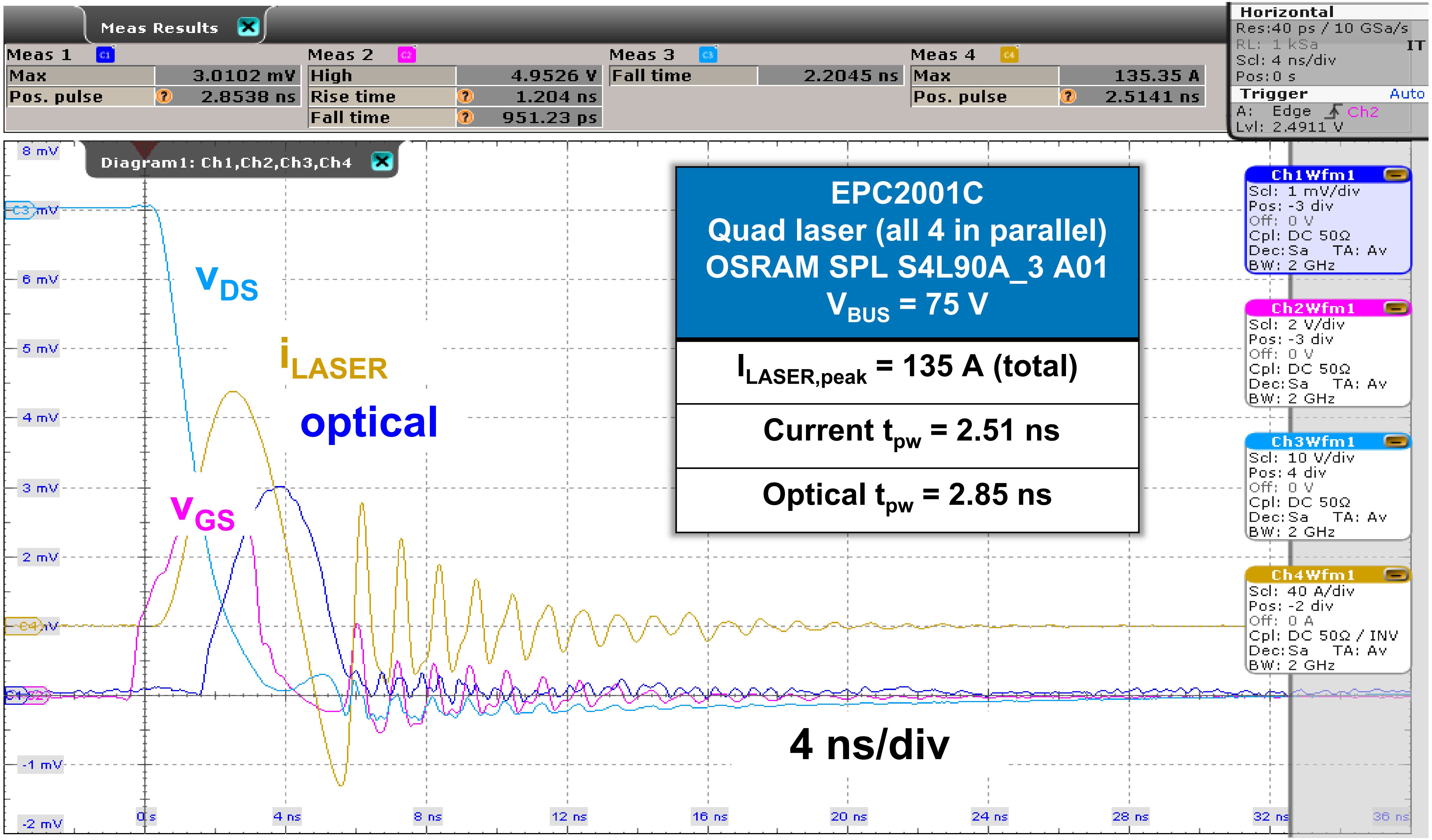
MMCX Molex 0734152063

- Breakaway boards for many lasers
- Other breakaway boards for alternate loads

EPC9126 Rev 3 (DToF)

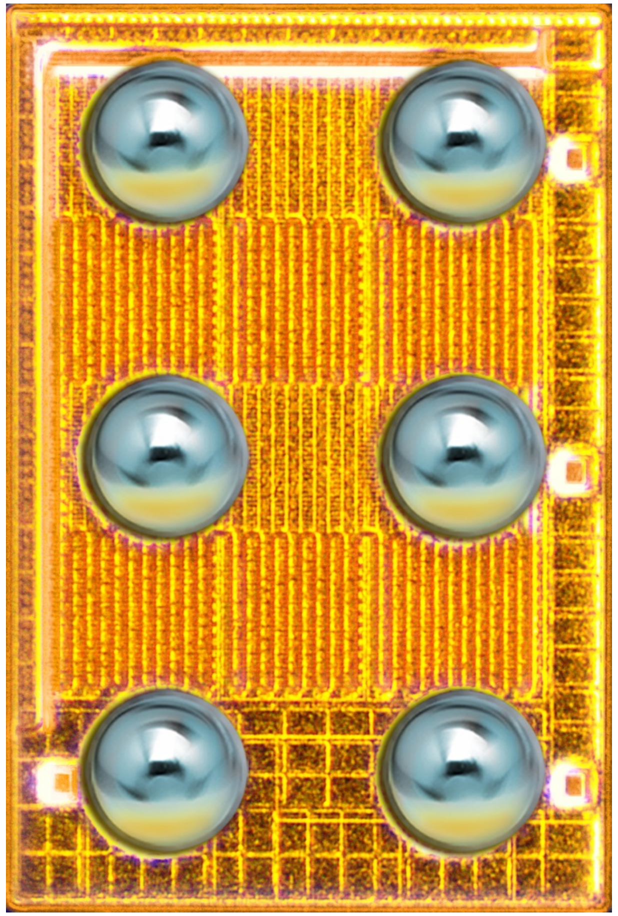


High Current EPC9126HC (DToF)



EPC2216 for *Picosecond* Speeds

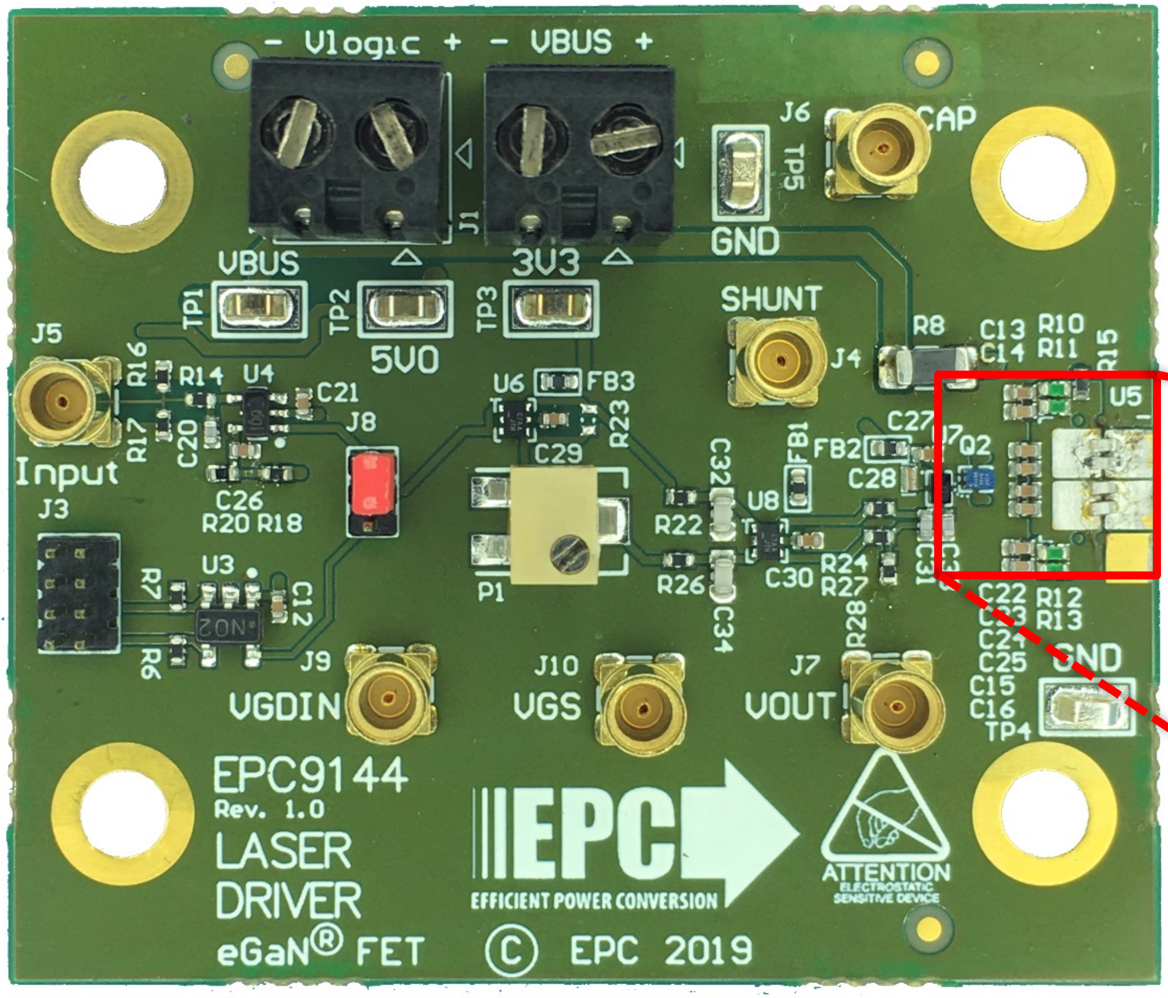
- **EPC2216 eGaN® FET**
  - 15 V, 3.4 A, 20 mΩ
  - 2 x 3 BGA
  - **870 pC gate charge**
  - **28 A pulse current**



0.85 mm x 1.2 mm

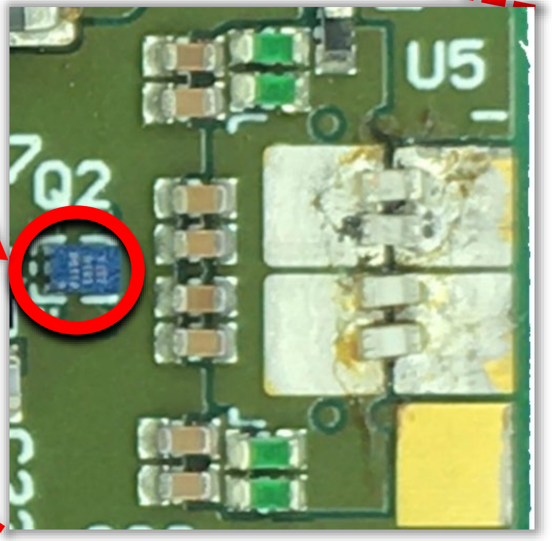
AEC-Q101 Automotive Qualified!

EPC9144 (IToF)



< 200 pH intrinsic power loop inductance!

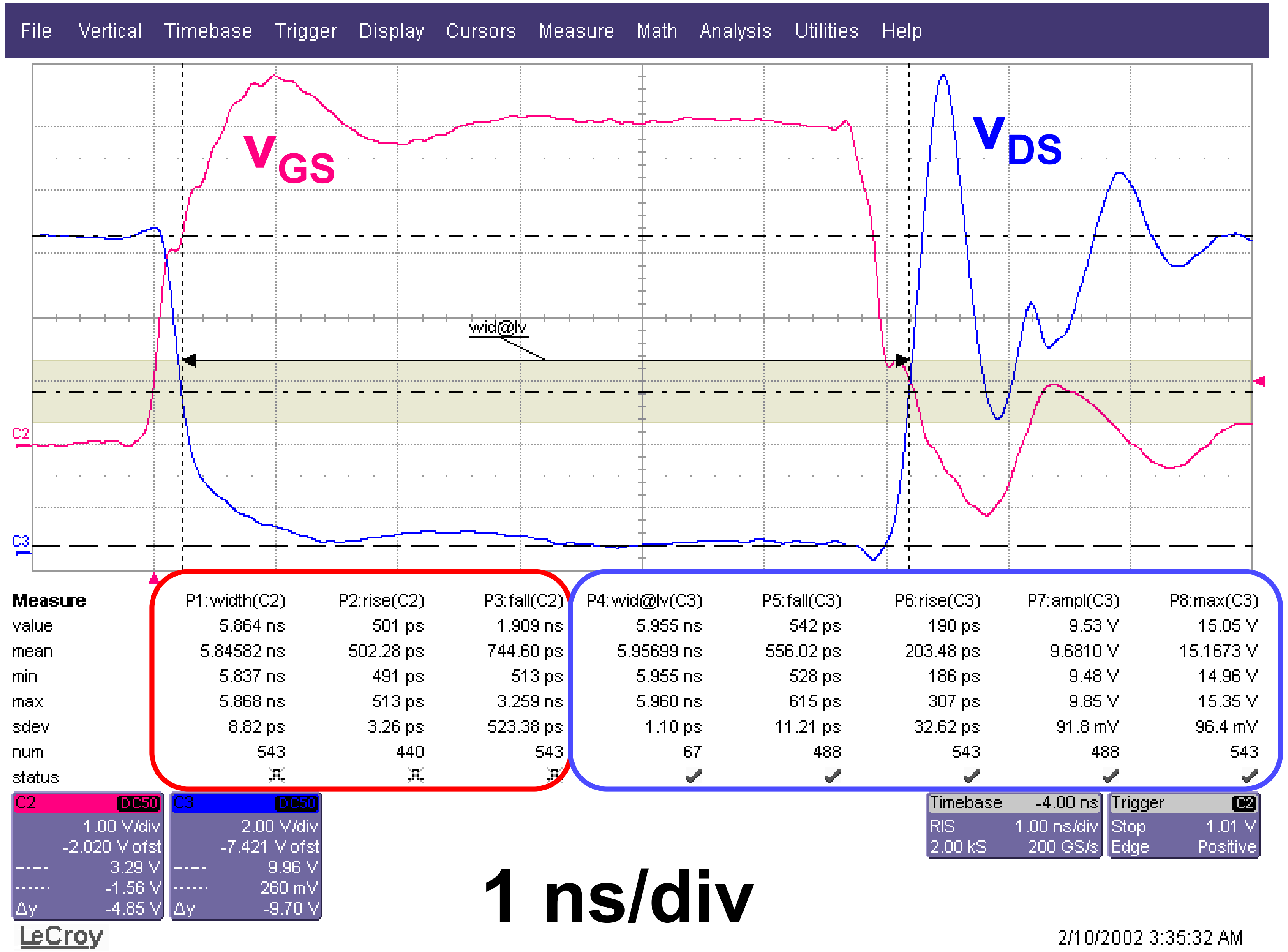
EPC2216



Driver stage detail

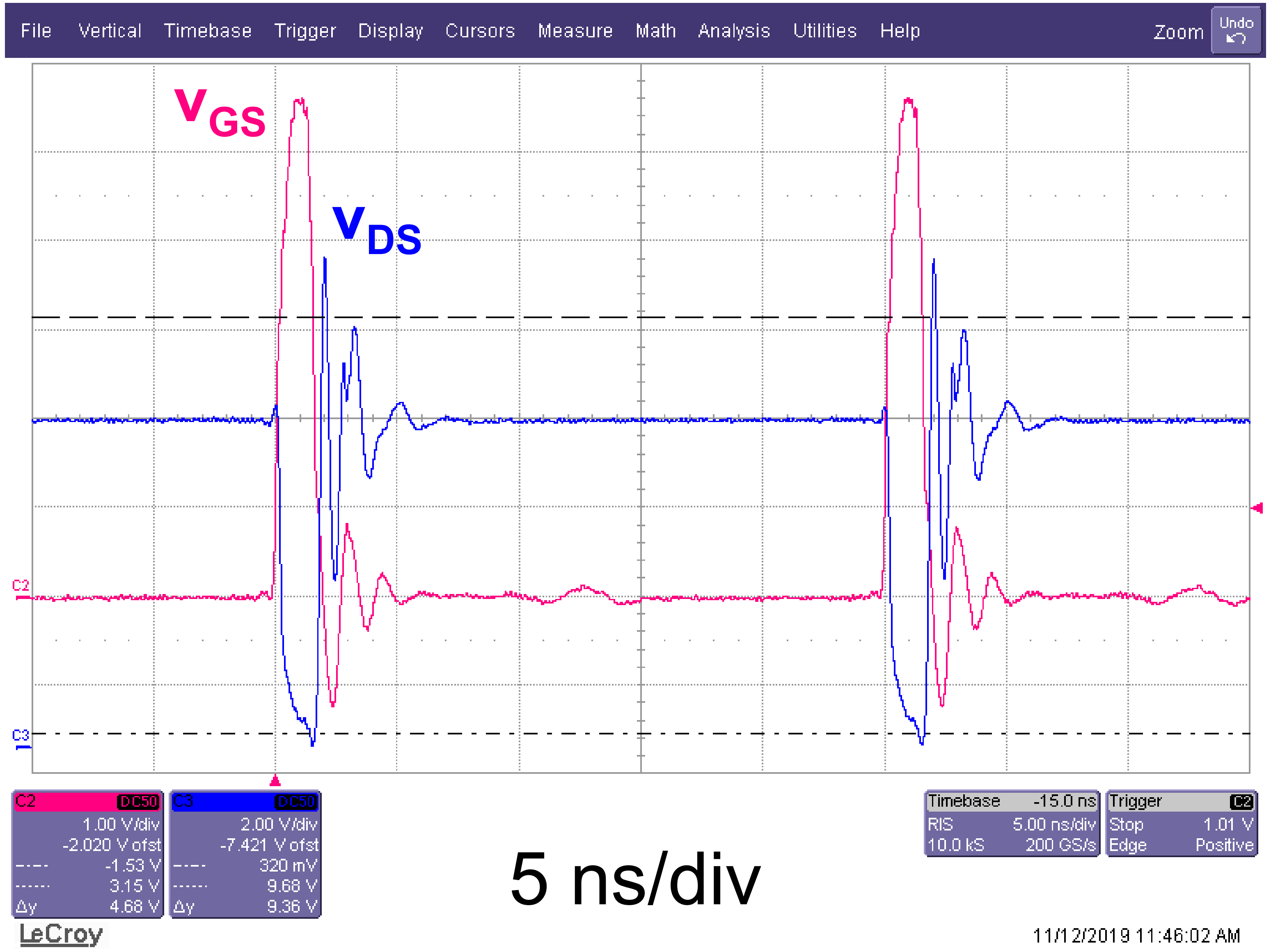
Long Pulse V_{BUS} = 10.1 V

- 1 Ω resistor load
- $I_{DS,max}$ = 9.9 A
- t_{on} = 556 ps
- t_{off} = 203 ps

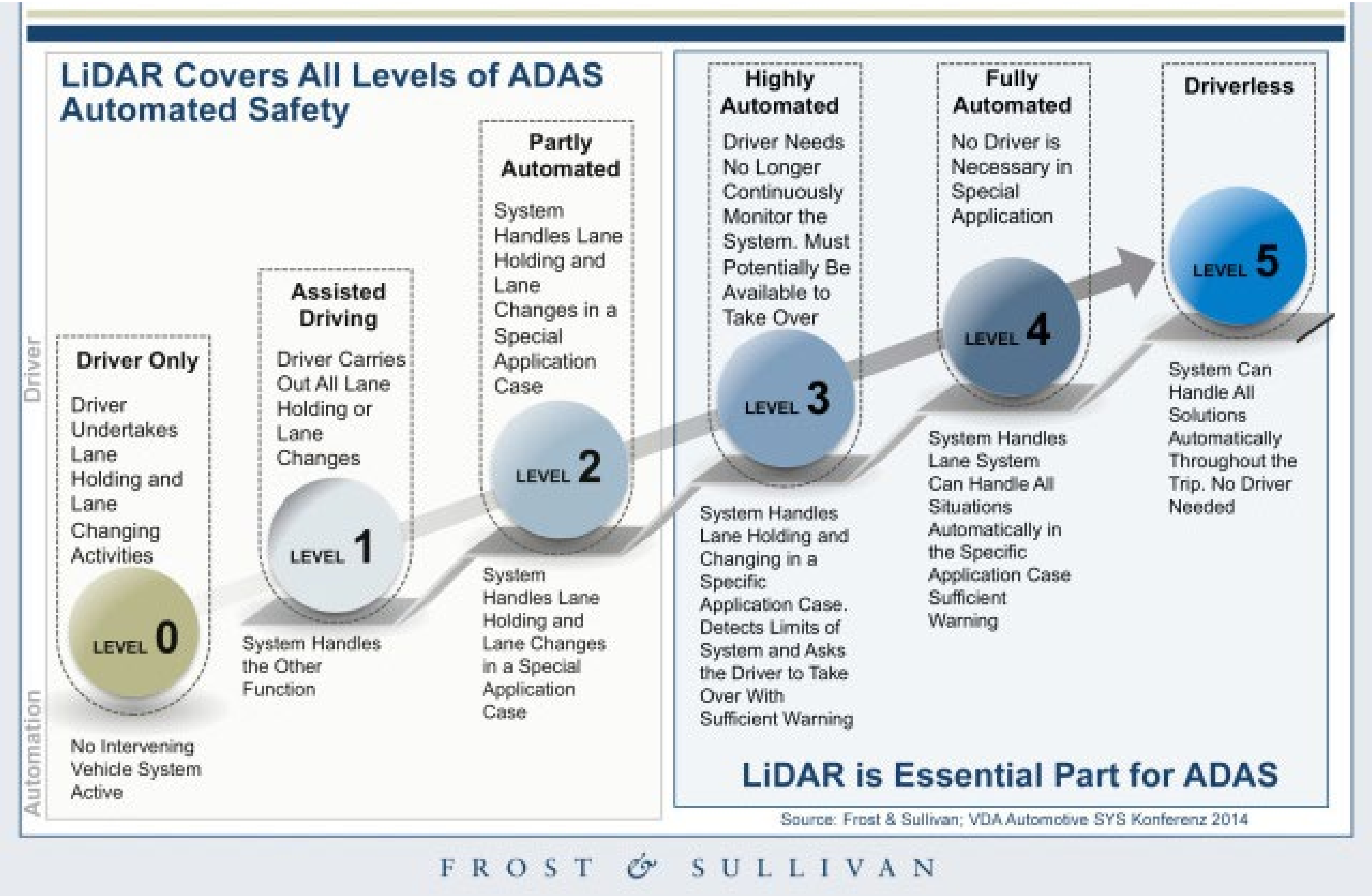


High Frequency V_{BUS} = 7.9 V

- 1 Ω resistor load
- $I_{DS,max}$ = 7.4 A
- t_w = 1.2 ns
- f_{pulse} = 40 MHz



The Pathway to Self Driving Cars

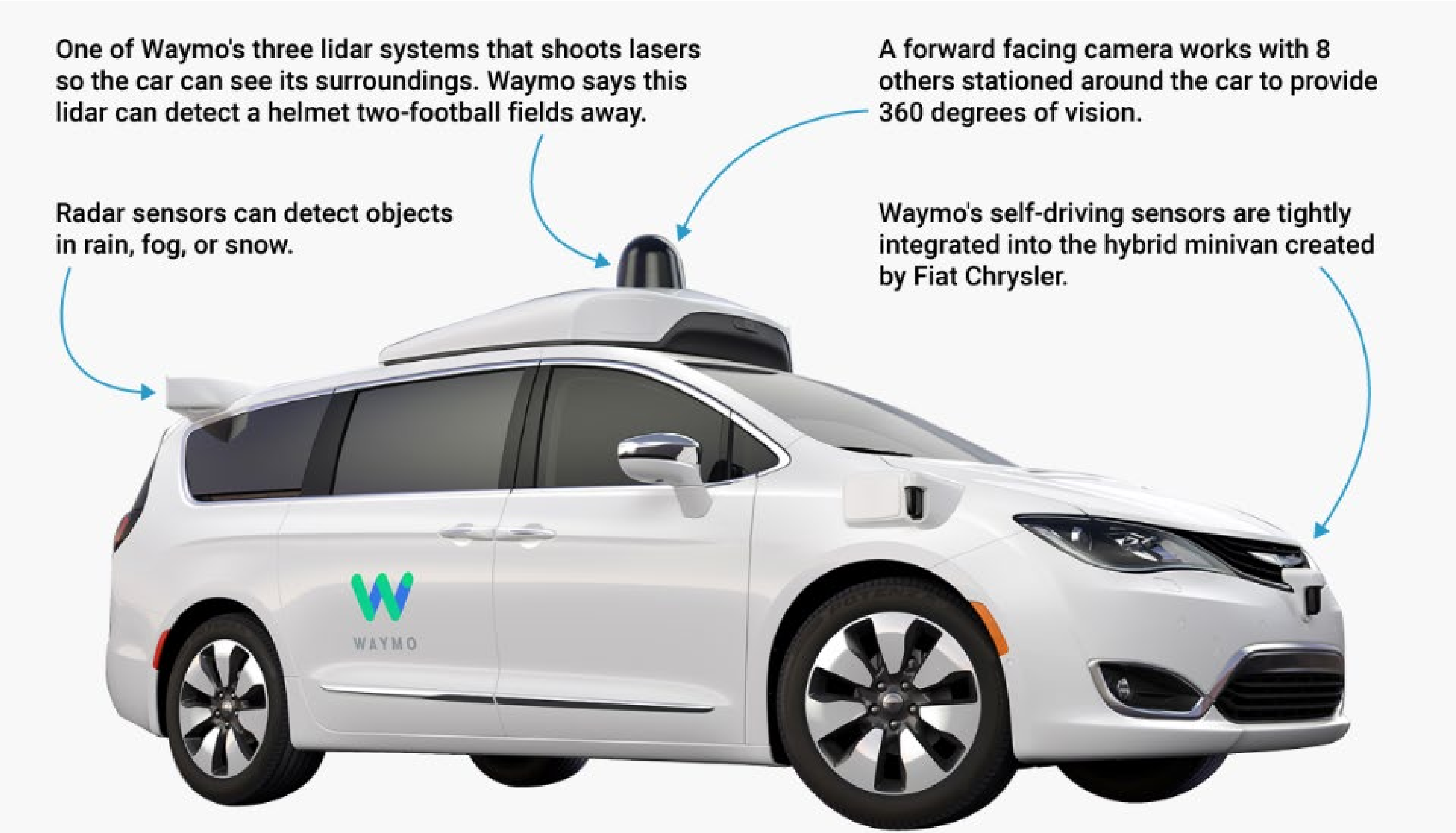


What is Required for Autonomous Cars?

300 meters (Approximately 11 seconds at 60 mph)

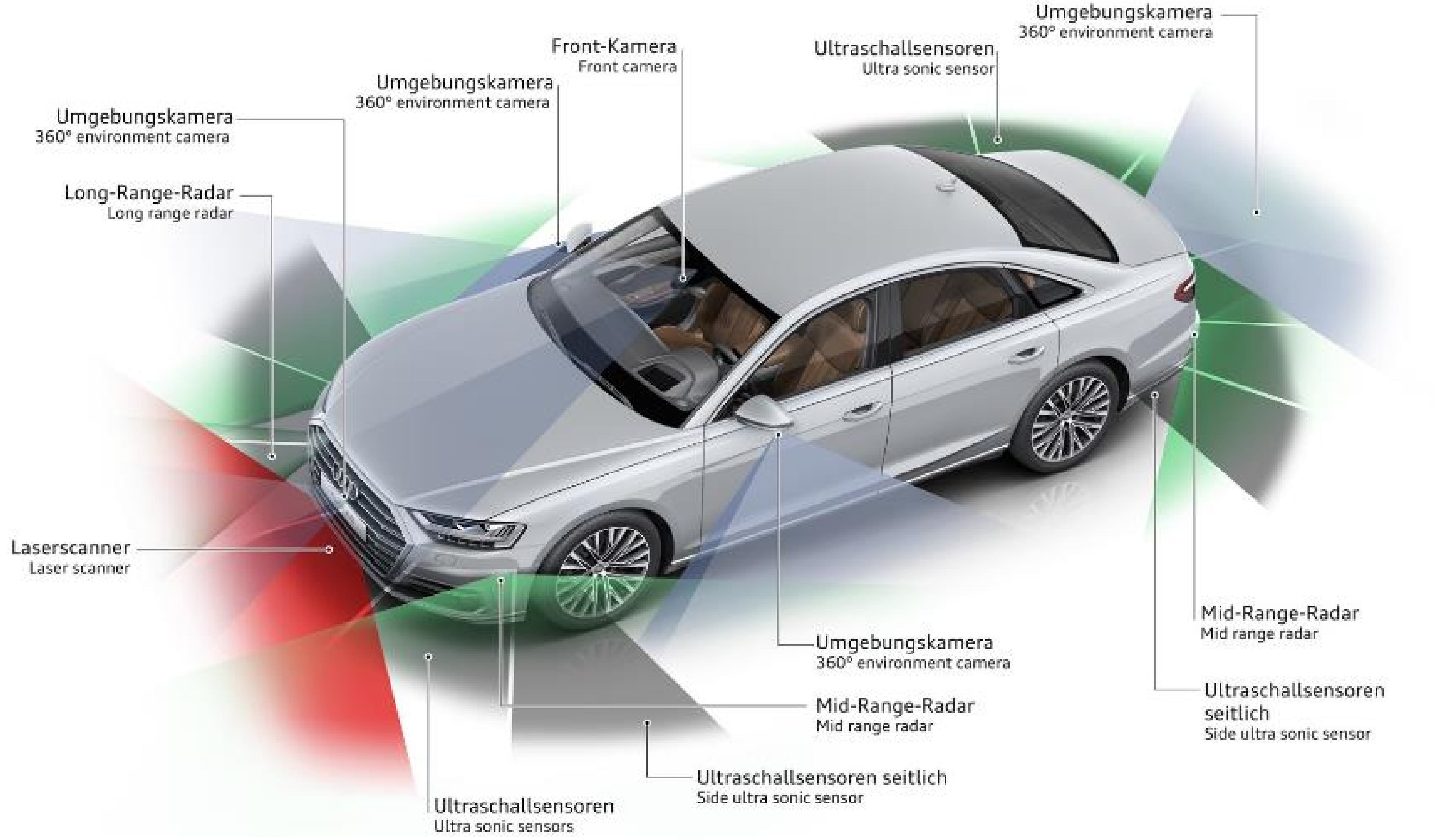
- Higher output lasers
  - Going to longer wavelengths (1500 nm vs 903 nm) allows for higher output power without danger to the human eye.
    - 1440 nm lasers and detectors are more expensive
  - Edge emitting LEDs are more efficient than VCSEL and have superior brightness
    - VCSEL lasers can be lower overall cost, but shorter range
- More sensitive detectors
  - Geiger mode can detect single photons but takes time to “reset”.

How Waymo’s Self Driving Car “Sees”



Source: Waymo

How Does Audi's ADAS A8 "See"



http://images.car.bauercdn.com/pagefiles/74157/audi_a8_level3_01.jpg

Lidar Myths

- Lidar can’t see in fog, snow or rain.
  - Lidar can see as well as, or better than a human.
- Spinning disk Lidar is unreliable.
  - There are lots of reliable spinning disks in every car.
- Lidar is too expensive.
  - Flash Lidar is much less expensive than spinning Lidar
  - Automotive companies have a way of grinding down cost.

The Future

- Lidar will be used on all cars.
- Lidar will be about as expensive as a headlamp.
- Lidar (scanning) +Lidar (flash) + Camera will be able to handle most autonomous functions.

Upcoming Trends

- Laser arrays
- Fewer lasers in a system
- MEMS/solid-state beam steering
- Automotive uptake slow and steady
- Commercial, consumer, industrial taking off
- Huge innovation in optics and detection technology