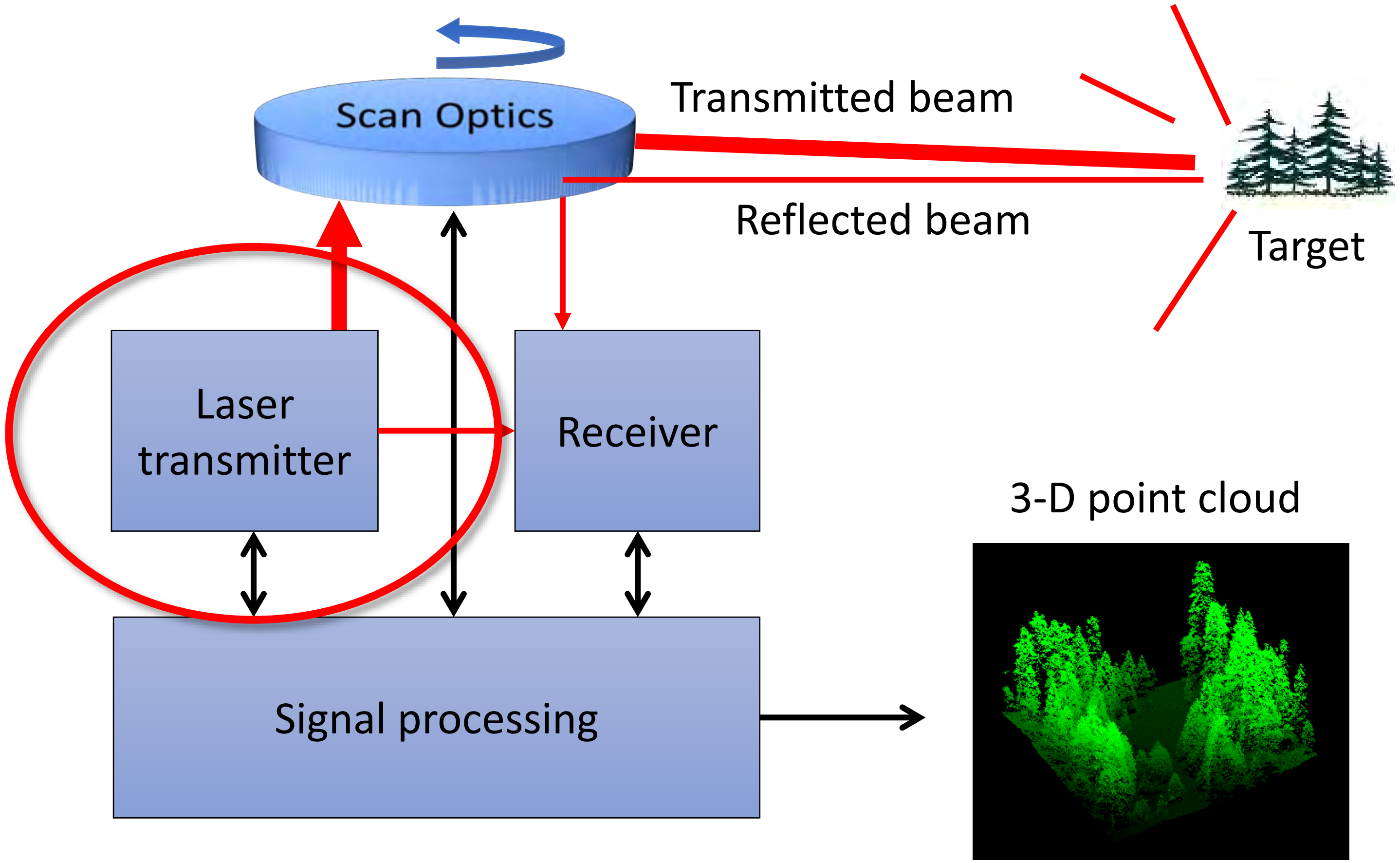
GaN-based Solutions for Cost Effective Direct and Indirect Time-of-Flight Lidar Transmitters

Alex Lidow, EPC

Overview

- Introduction to lidar and laser diode drivers
- Why GaN?
- Do picoHenries matter?
- State-of-the-art
- The future

What is Lidar?



http://ucanr.edu/blogs/green//blogfiles/11605_original.png

Types of lidar

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

Where is ToF Lidar Used Today?

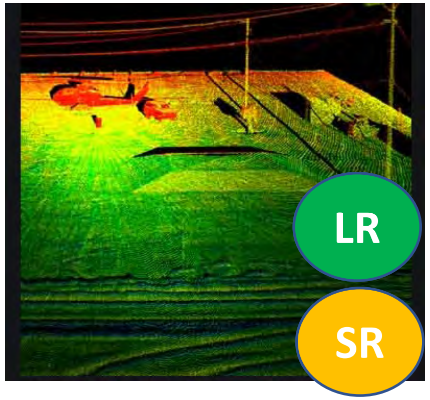
Automated Guided Material Handling Robot

Drone Navigation and 3-D Mapping

Lidar Robotic Vacuum

Humanoid Robots and Cobots

Lidar Robotic Delivery Vehicles

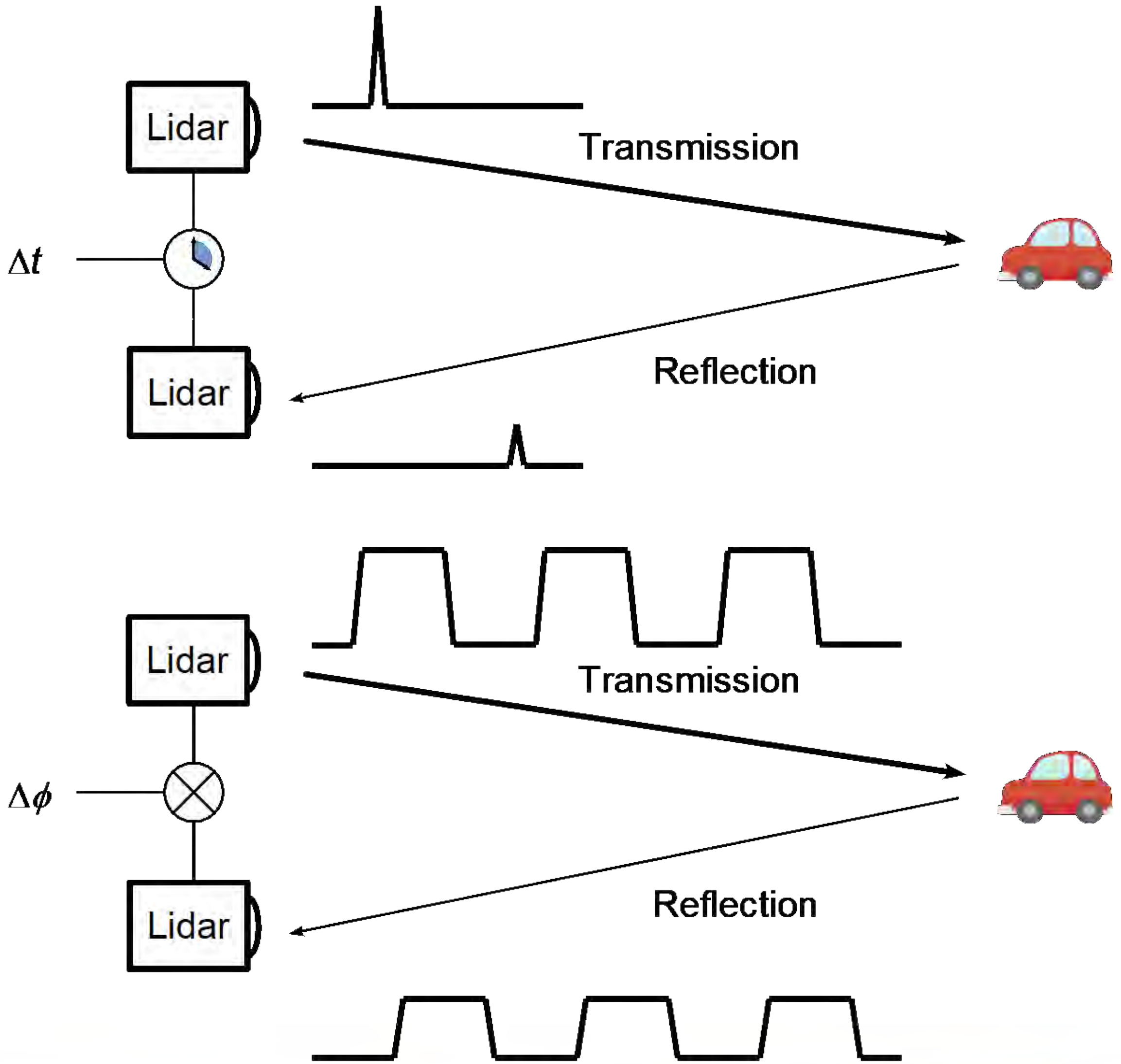


Lidar Surveillance Systems

Lidar Robotic Security Robot

Autonomous Vehicle Navigation

Direct versus Indirect (DToF vs. IToF)



Direct (DToF)

Measure time difference between TX and RX pulse

- Long range
- single point/laser
- fancy optics

Indirect (IToF)

Measure phase difference between TX and RX envelope

- “Flash” lidar
- Imaging chip detector

Importance of pulse shape (DToF)

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

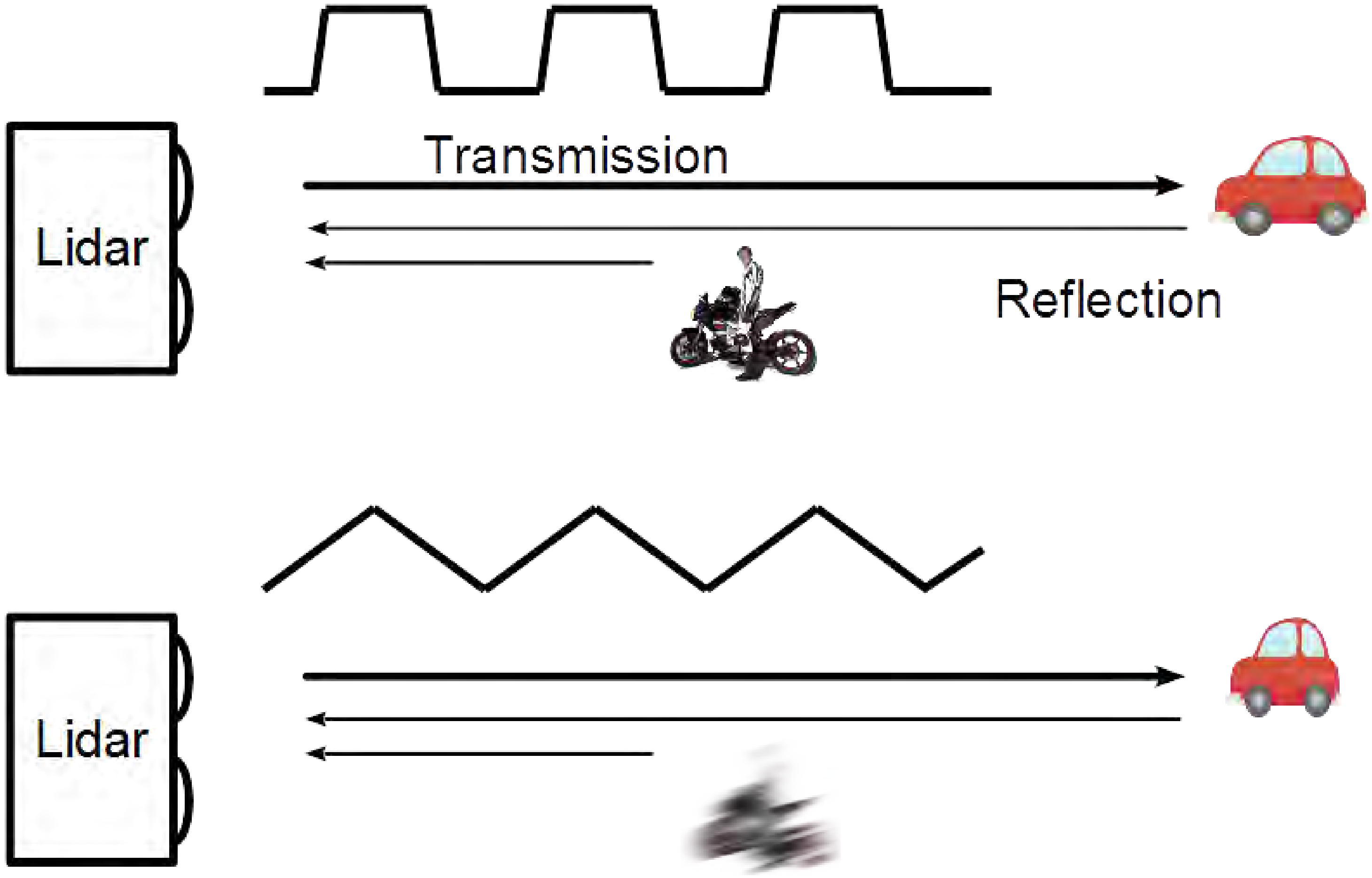
t_{d1} t_{d2}

$$\frac{c\ \times 1\ \text{ns}}{2} = 15\ \text{cm}$$

??

Shorter pulse = better resolution

Importance of pulse shape (IToF)



Fast transition

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

Slow transition

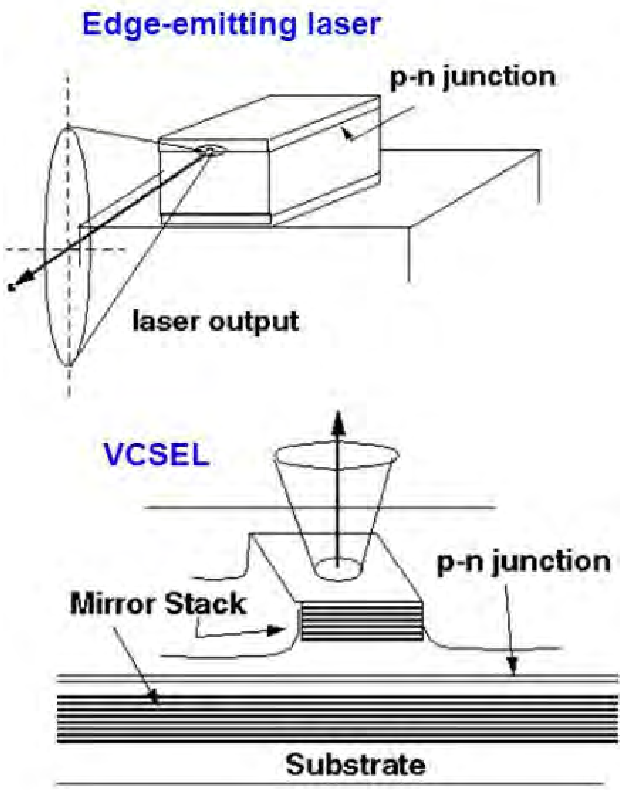
- Nonlinear response
- Extra computation required

Amplitude (DToF and IToF)

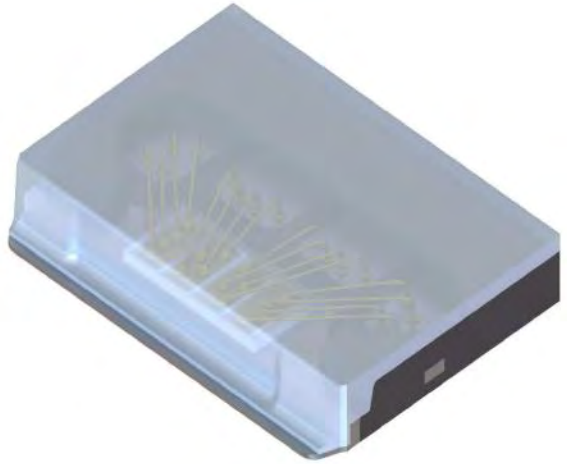
- Higher pulse amplitude = increased range
- Pulse energy limits:
  - Laser thermal limitations
  - Eye safety limits
- Narrower pulse affords higher amplitude

Laser Diodes

- Laser diodes are most common light source
  - Fast response, 100 ps or less
  - Peak optical power from < 1 W to > 1 kW
  - Cost effective
  - Available in useful wavelengths (850 nm, 905 nm, 940 nm, 1550 nm)



Introduction to nanophotonics Alexey Belyanin Department of Physics, Texas A&M University



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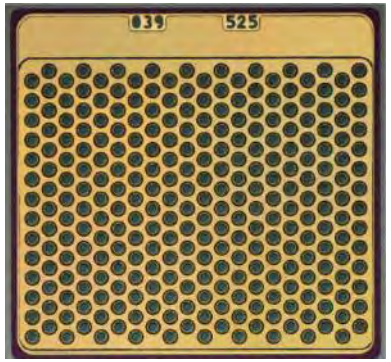
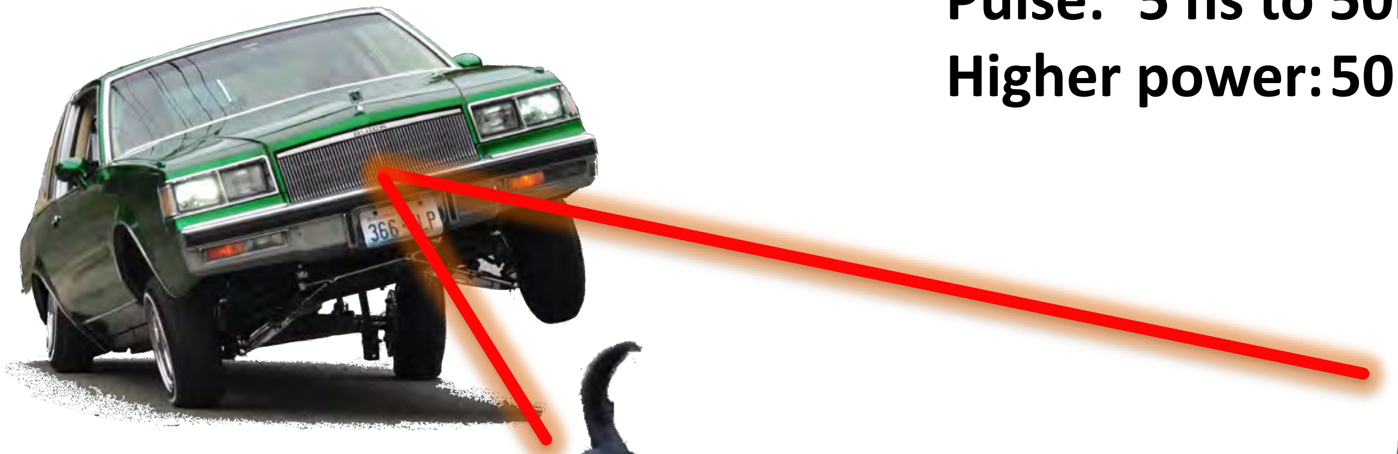


https://ii-vi.com/product/high-power-vcsel-array/

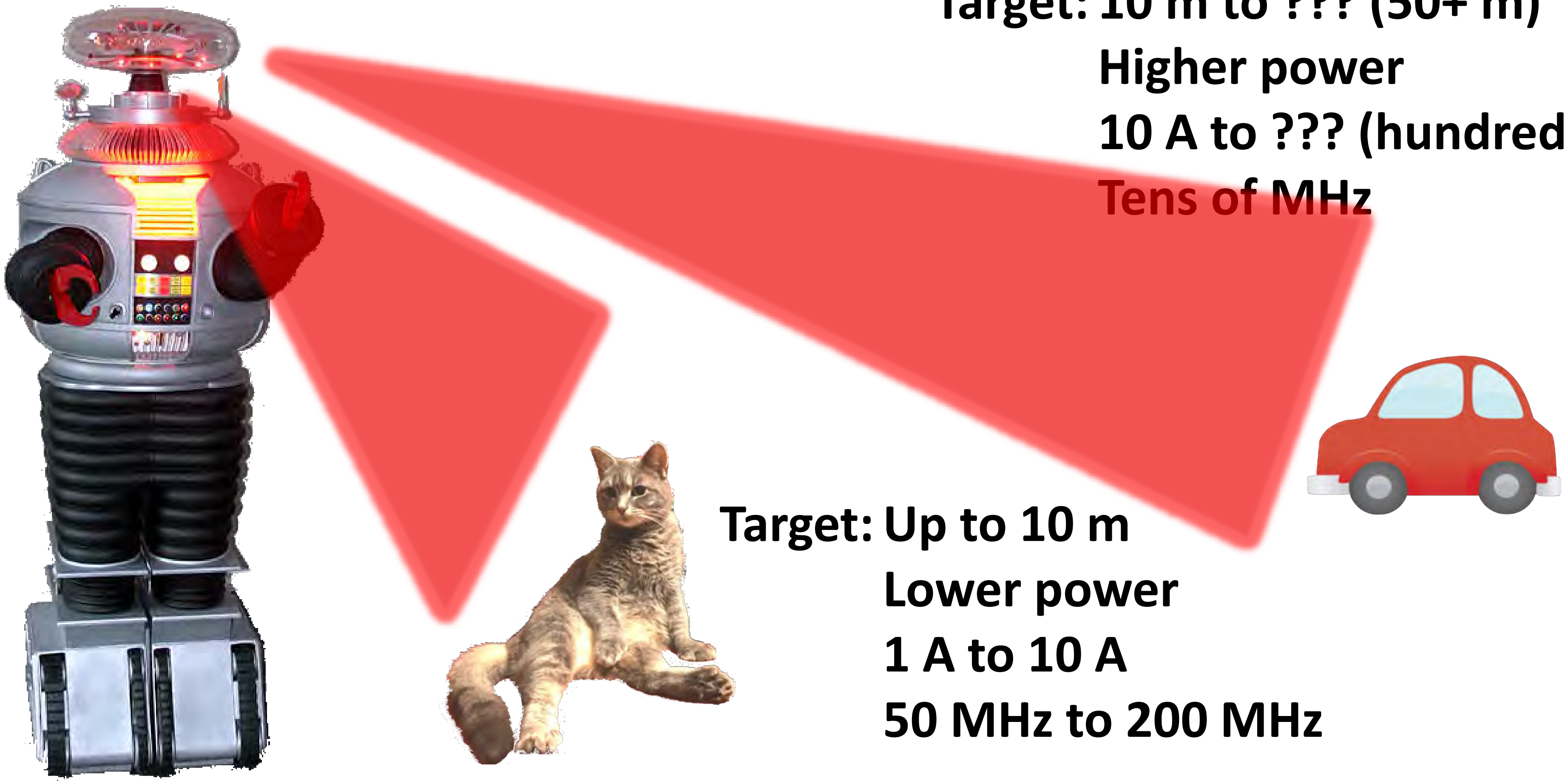
DToF Pulse Width and Amplitude

Target: Up to 200 m to 300 m
Pulse: 5 ns to 50ns
Higher power: 50 A to 500 A



Target: Up to 10 m
Pulse: 0.5 ns to 5ns
Lower power: 5 A to 50 A

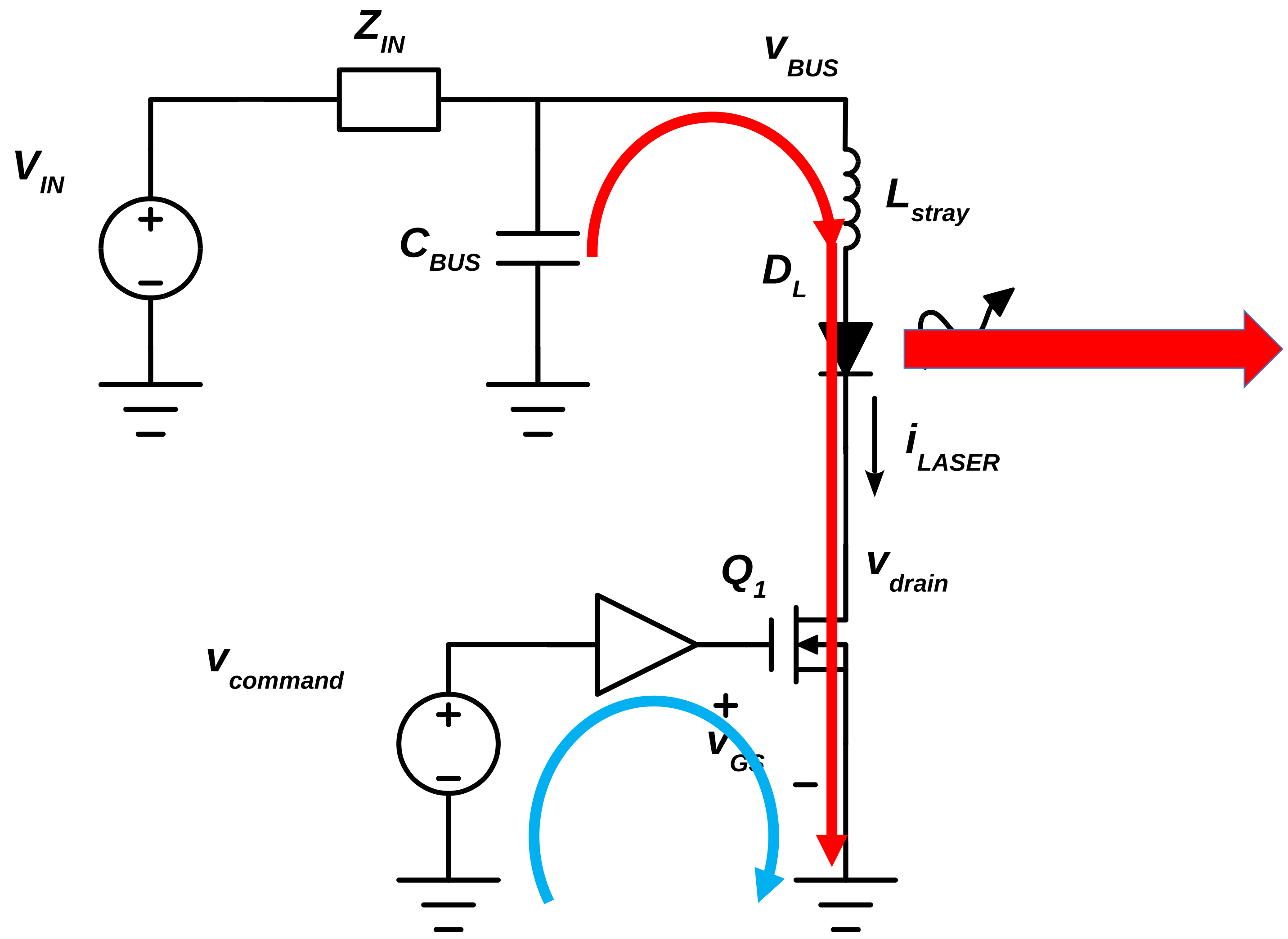
IToF Pulse Width and Amplitude



Target: 10 m to ??? (50+ m)
Higher power
10 A to ??? (hundreds)
Tens of MHz

Target: Up to 10 m
Lower power
1 A to 10 A
50 MHz to 200 MHz

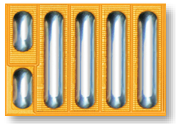
Laser Driver Circuit



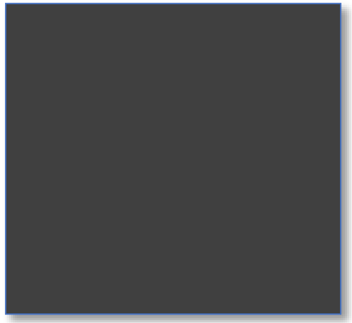
Why GaN?

Parameter	EPC2212	Best in class
Technology	eGaN 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} [Ω]	0.4	1.0
R_{gate}•Q_{Gtot} [Ω•nC]	1.3	7.6
L_{gate} [nH]	< 0.1	3.0
L_{source} [nH]	< 0.05	0.3
L_{drain} [nH]	< 0.05	1.0
Package [mm x mm]	LGA 2.1 x 1.6	DFN 3.3x3.3
AEC Q101	YES	NO

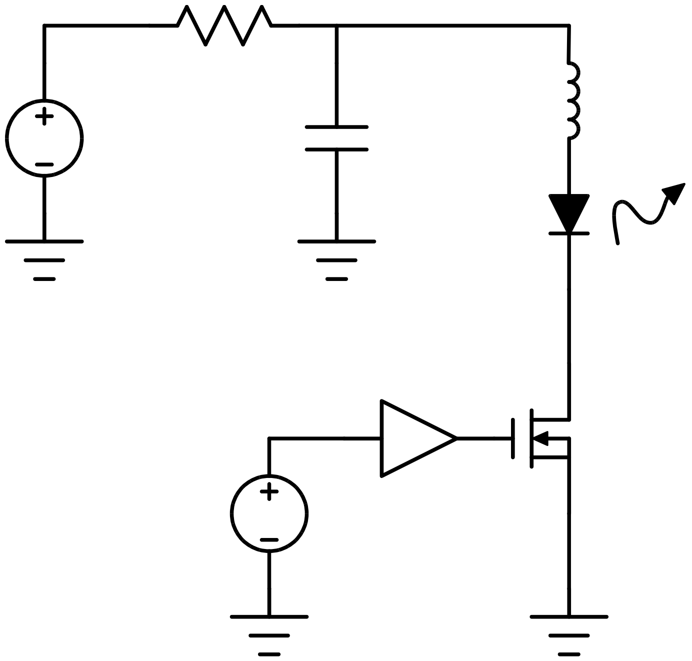
eGaN FET

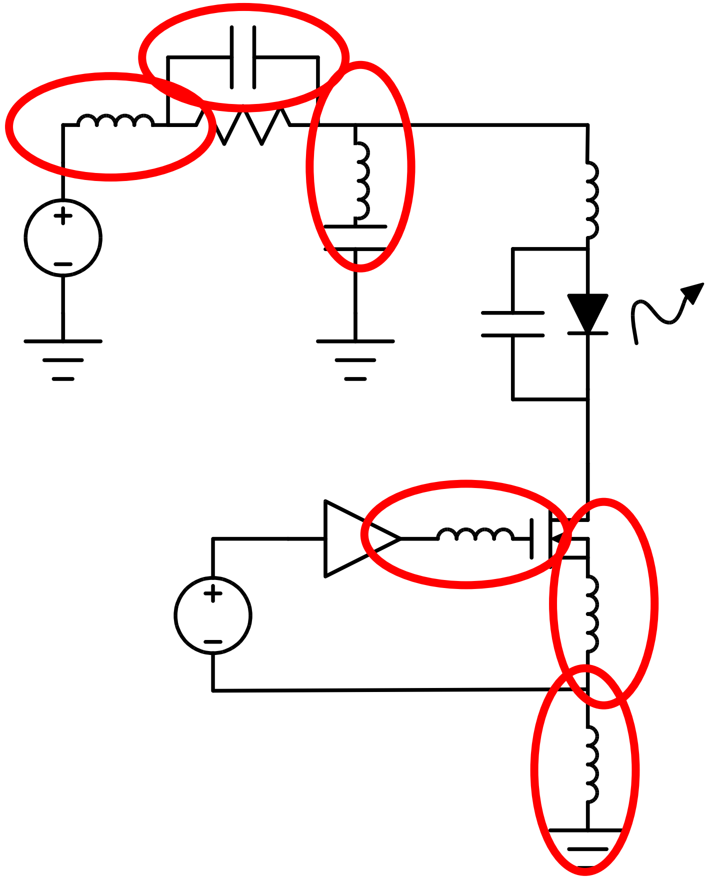


Si MOSFET



Simple?

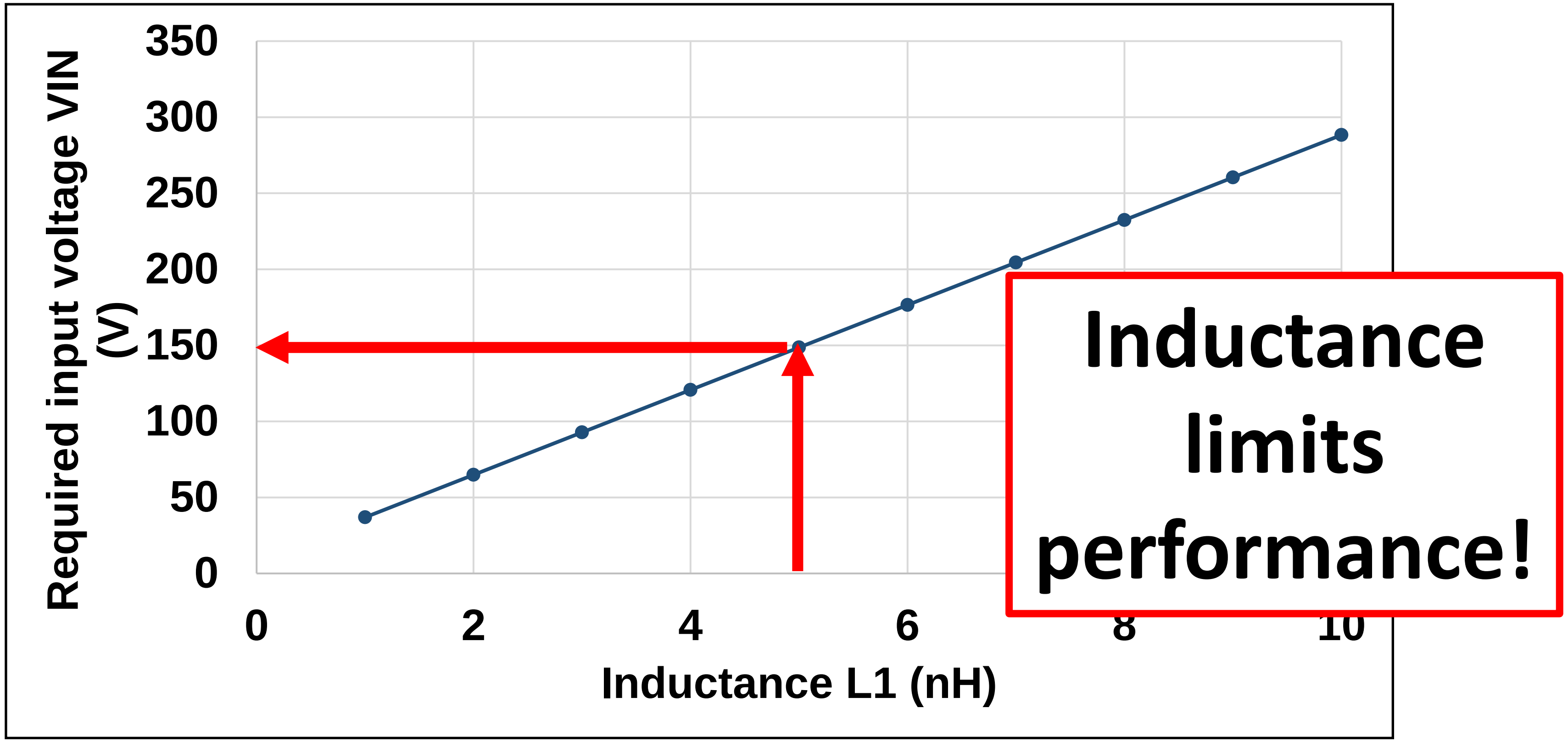




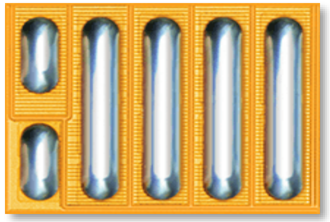
Not so simple…

Impact of Power Loop Inductance

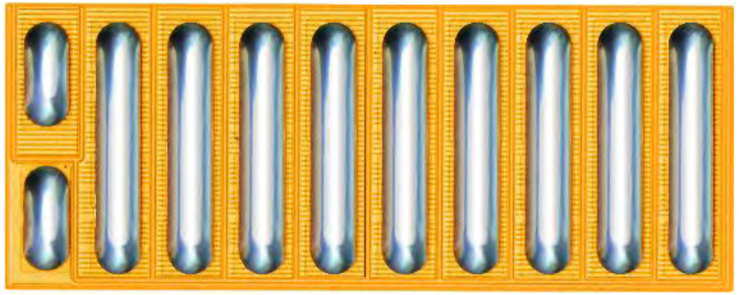
Design conditions: Peak current $I_{DL,pk}$ = 40 A, t_w = 3 ns



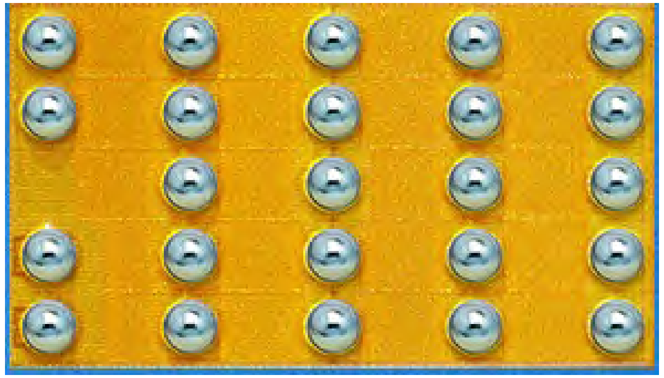
Low Inductance Starts With FETs



EPC2212
100 V
75 A pulse

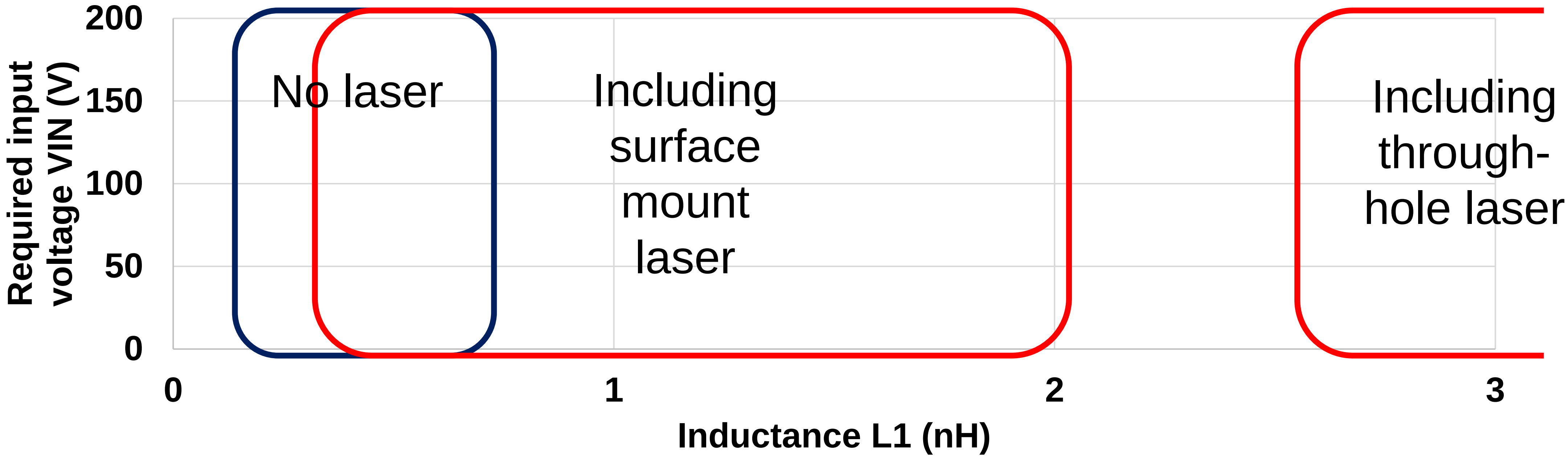


EPC2001C
100 V
150 A pulse



EPC2034C
200 V
213 A pulse

Practical Power Loop Inductance

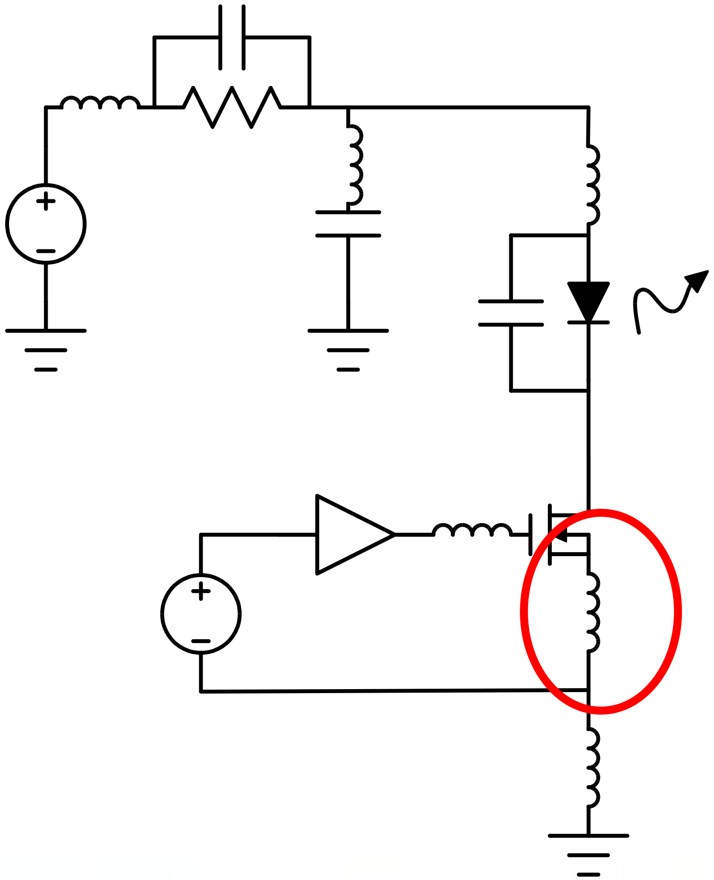


Power loop includes:

- Main Power FET (chip scale package)
- Capacitor bank
- Mounting area for laser diode
- Current measurement shunt (in some cases)

Question: Does 50 pH Matter?

Answer: Yes, if it's common source inductance (CSI)



Typical di/dt:

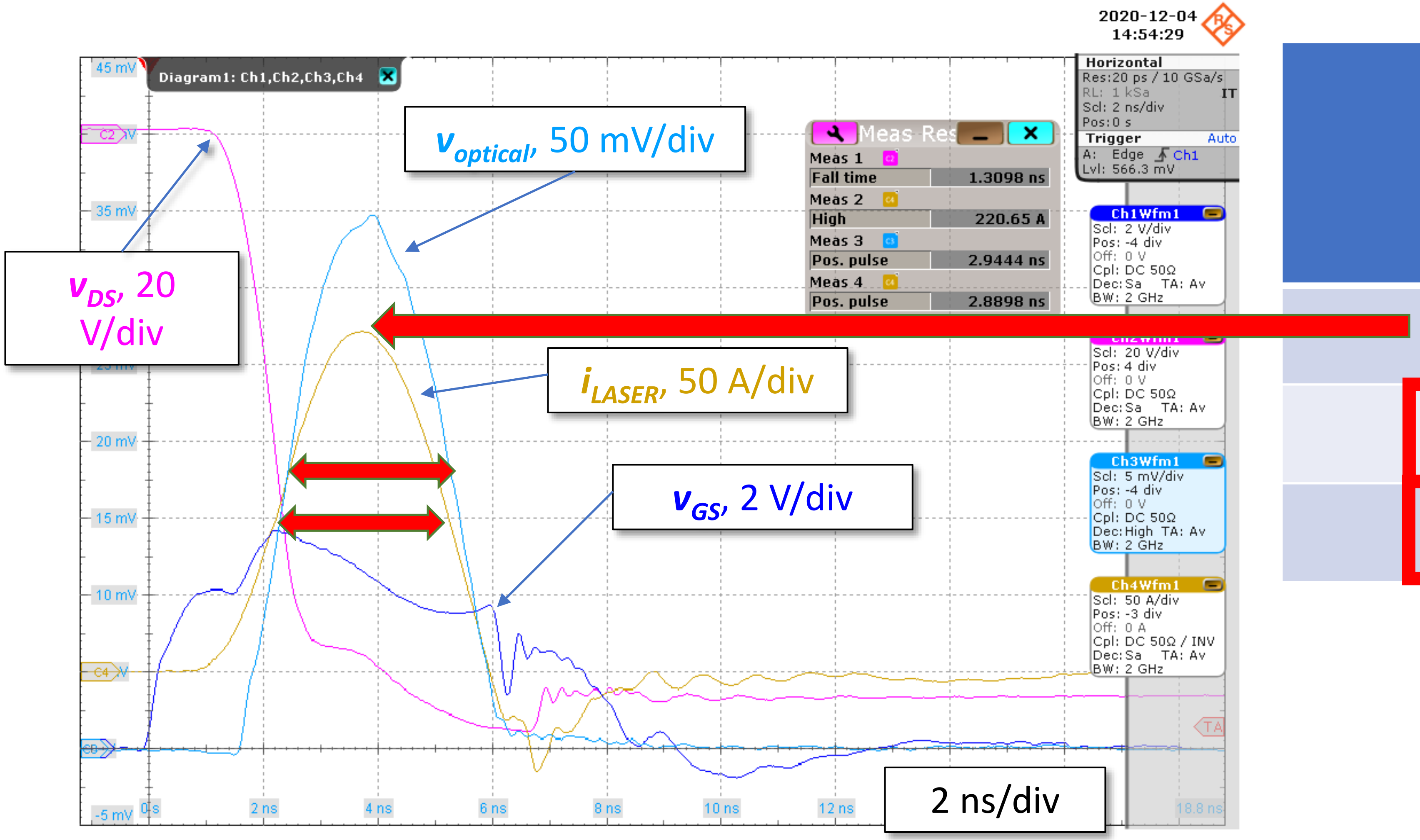
$$\frac{di_S}{dt} = \frac{di_D}{dt} = \frac{100\ \text{A}}{\text{ns}}$$

$$L_{CSI} = 50\ \text{pH}$$

$$v_{CSI} = L_{CSI}\frac{di_S}{dt} = 5\ \text{V}$$

50 pH matters a lot!!

EPC2034C 200 V eGaN FET



FET EPC2034C
4x1 laser B
V_{bus} = 150 V

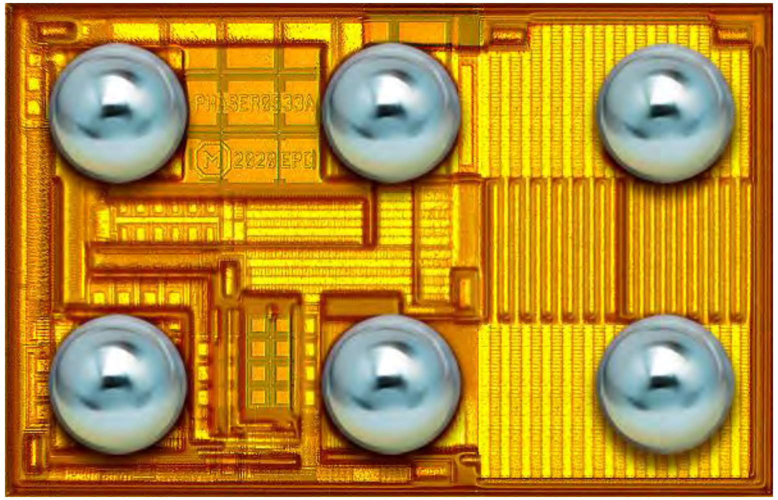
$I_{LASER,peak}$ = 221 A
Current t_{pw} = 2.89 ns
Optical t_{pw} = 2.94 ns

What's New?

Even 10-20 pH CSI has noticeable effect on performance

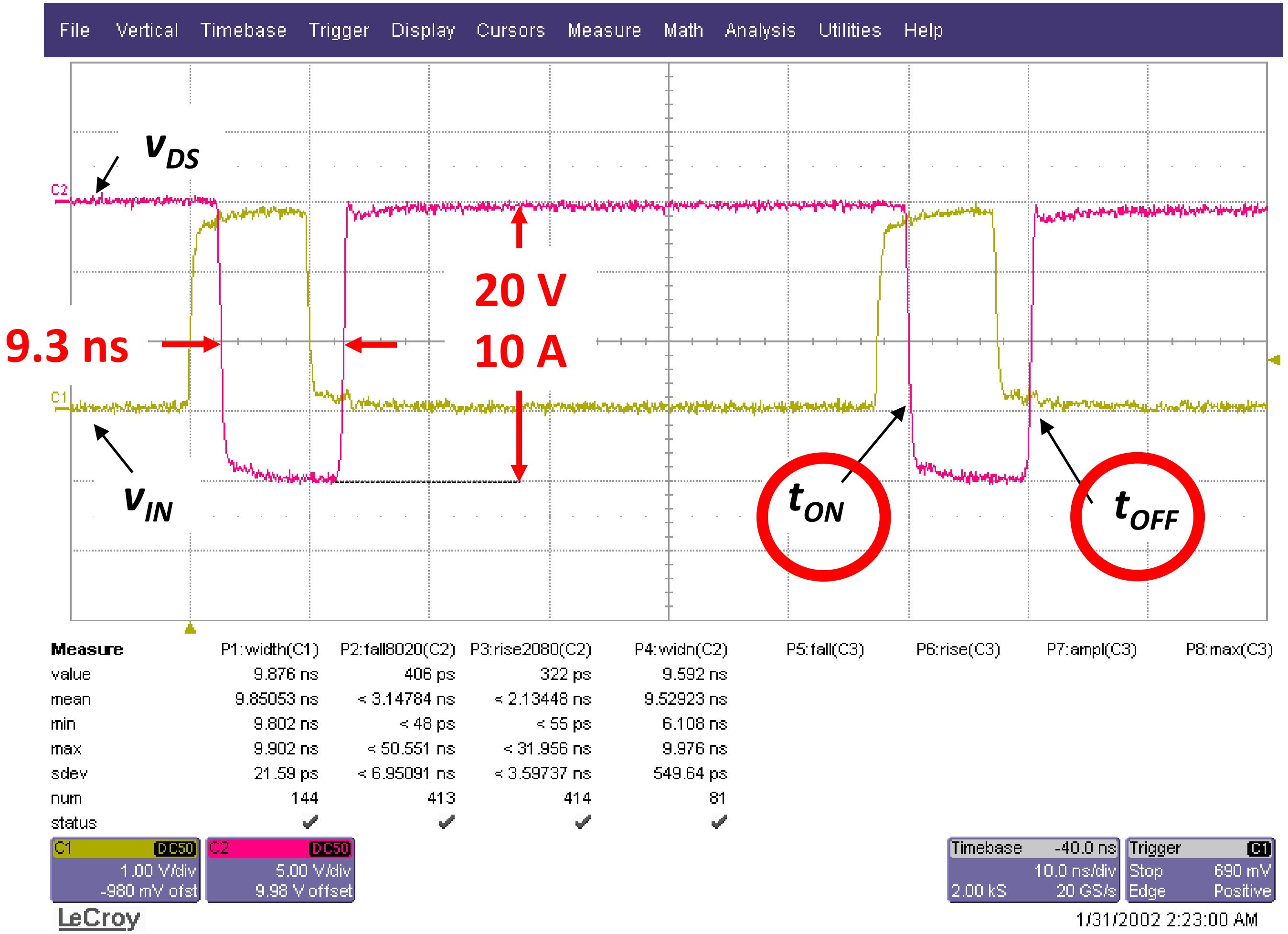
Integration
- Reduce CSI to a few pH
- Replace several parts with a single part
- Enhanced reliability
- Reduced driver area
- Reduced cost

EPC21601 Laser Driver IC
- 40 V, 10 A FET with integrated gate driver
- 3.3V logic level input



1.0 mm x 1.5 mm

EPC21601



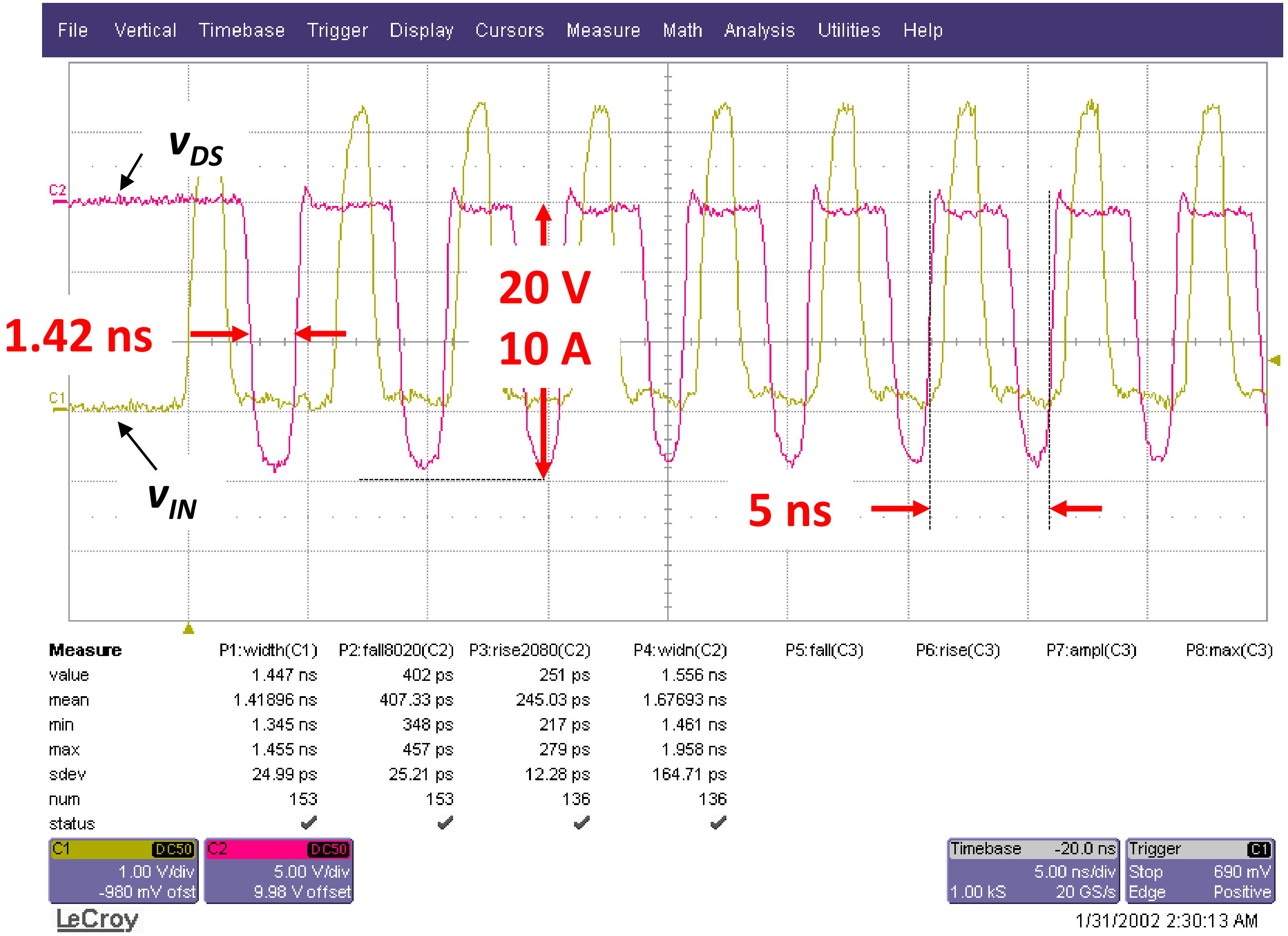
IC EPC21601
2 Ω resistive load
V_{bus} = 20 V

$I_{LOAD,peak}$ = 10 A

v_{DS} t_{ON} = 410 **ps**

v_{DS} t_{OFF} = 320 **ps**

EPC21601



IC EPC21601 2 Ω resistive load V_{bus} = 20 V
$I_{LOAD,peak}$ = 9.3 A
v_{DS} t_{ON} = 407 **ps**
v_{DS} t_{OFF} = 245 **ps**

200 MHz

ToF Laser Drivers

New IToF Driver

EPC9150
200 V, > 200 A

EPC9126 and EPC9126HC
100 V, 70A and 135A (HC version)

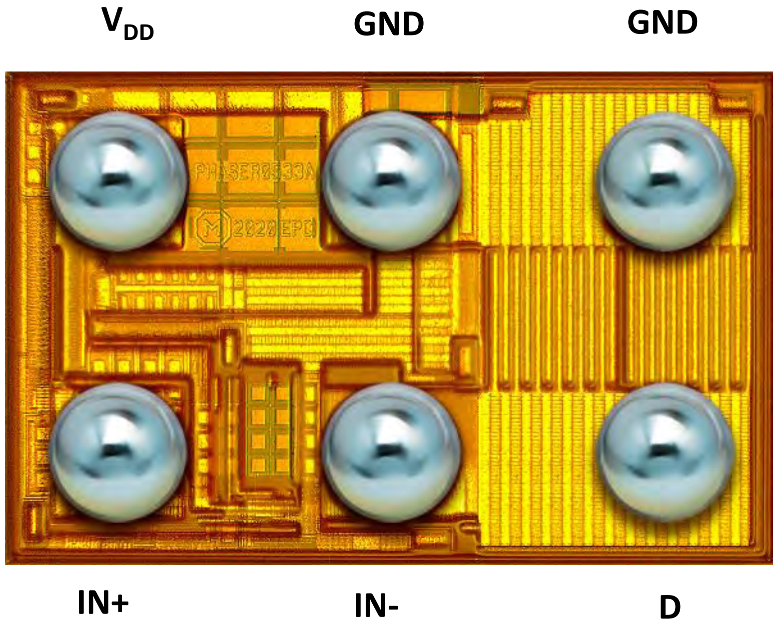
EPC9154
40 V, 10 A, 200 MHz

Schematics, Gerbers, and App notes available at EPC's website

What's Next?

EPC21603 Laser Driver IC

- 40 V, 10 A FET with integrated gate driver
- **LVDS (low voltage differential signal) input**

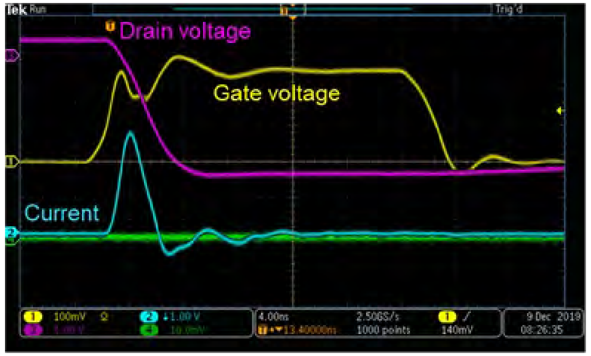


1.0 mm x 1.5 mm

March 16 Launch

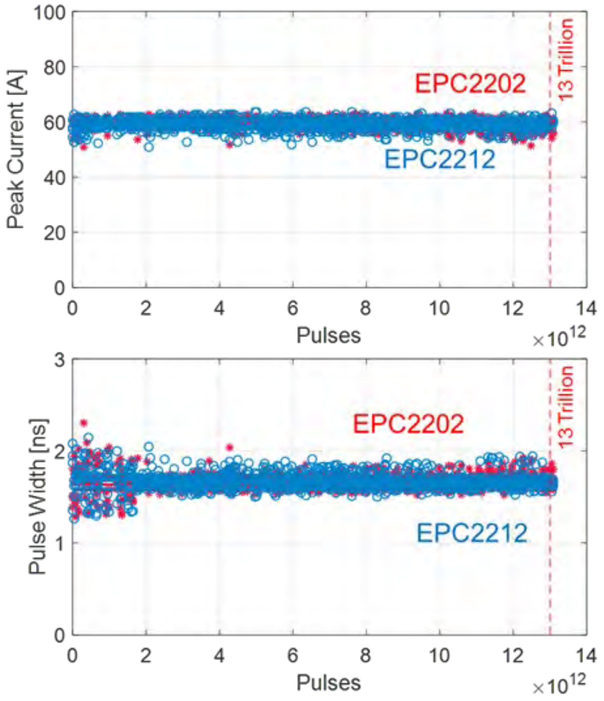
Reliability

Test waveforms

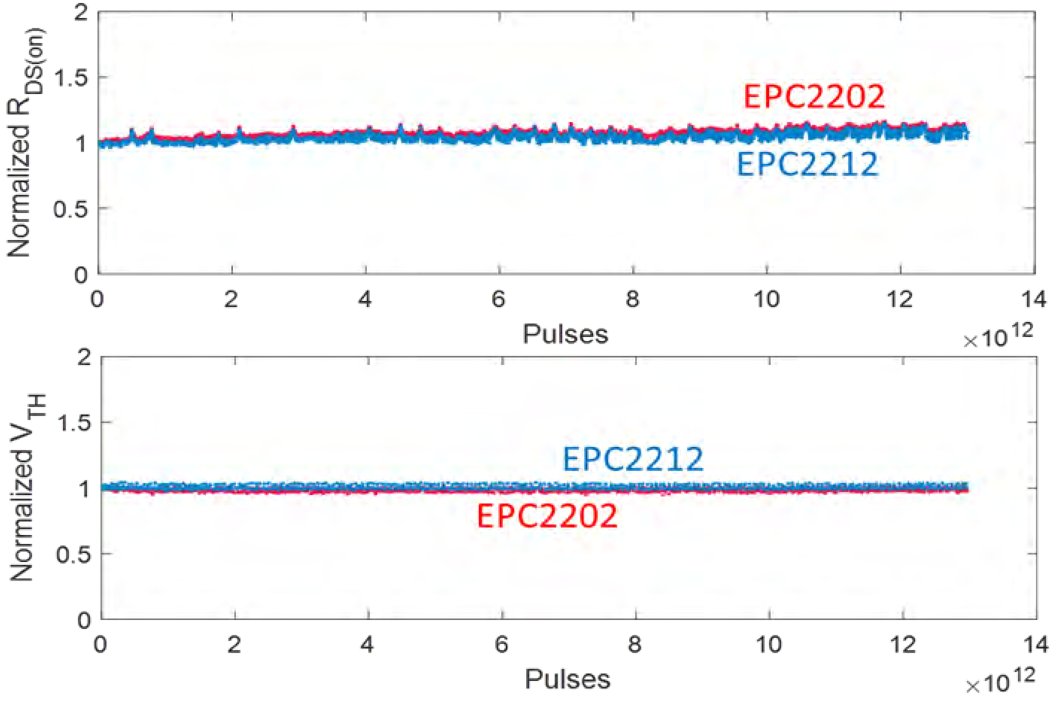


- AEC-Q101 series of discrete FETs
  - 8 samples (>7000h)
  - 0 failures and perfect pulse stability

Pulse performance



FET parameter stability



Stable after 13 Trillion Cycles

Conclusion

- Time-of-flight lidar drivers are a pulsed power application
- Pulse requirements differ with lidar range and purpose.
- When using GaN FETs, inductance dominates the design
- eGaN FETs are best choice for high performance laser drivers