GaN-based lidar pulse generator achieving 320 A in 6 ns: Design and system integration considerations

Edward A. Jones, PhD and Marcus Hennecke, PhD
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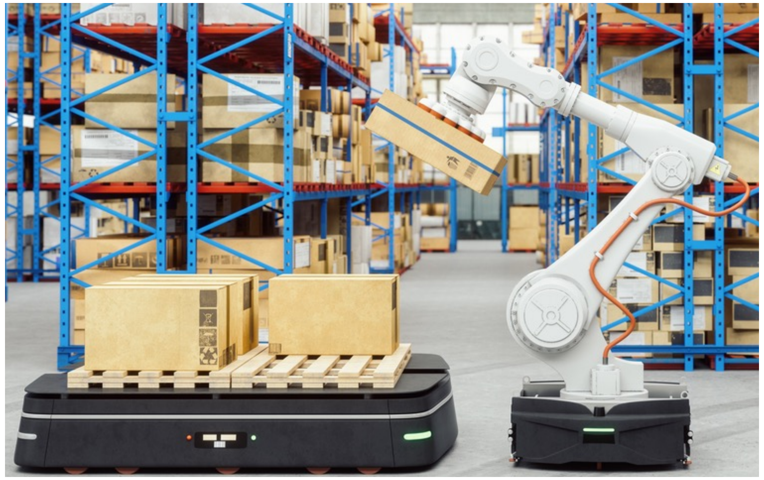
Speaker background

Dr. Edward A. Jones is a Principal Engineer for Infineon Technologies, specializing in GaN product definition and applications. He completed his Ph.D. at The University of Tennessee in 2017, and his B.S.E.E. in 2007 at Virginia Tech. Prior to joining Infineon, Edward was a Senior Application Engineer at Efficient Power Conversion. Dr. Jones has co-authored over 30 peer-reviewed papers, two professional education seminars, one patent, and the book *Characterization of Wide Bandgap Power Semiconductor Devices* published by the IET. He has also contributed to several other books, application notes, and invited talks. His research interests include wide bandgap device characterization and modeling, and GaN-based converter design.

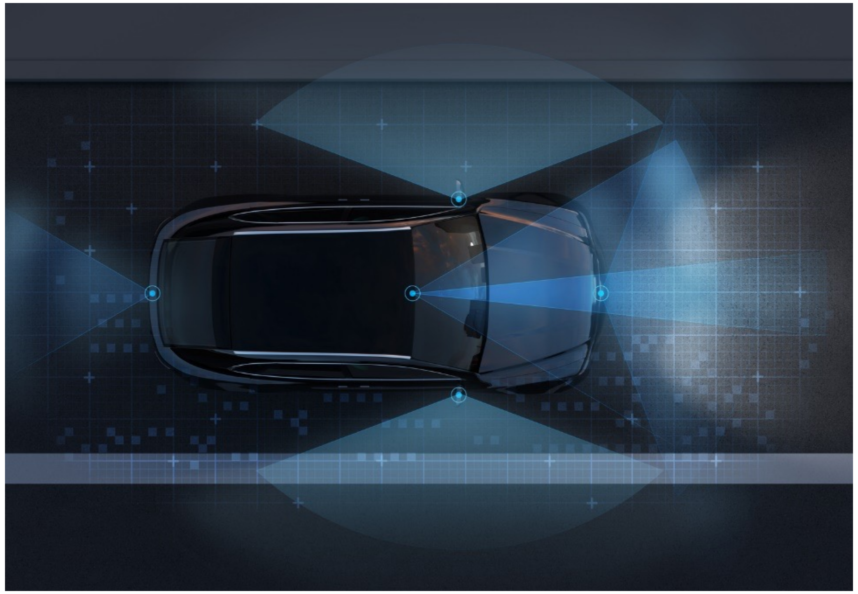
Outline

Introduction

- Light Detection And Ranging (LiDAR) is an important enabling technology for the future of autonomous vehicles
- Key performance criteria: range, resolution, frame rate
- Requires laser emitters with short pulses and high peak currents
- iLIDS4SAM Collaboration: Infineon + RIEGL + Silicon Austria Labs



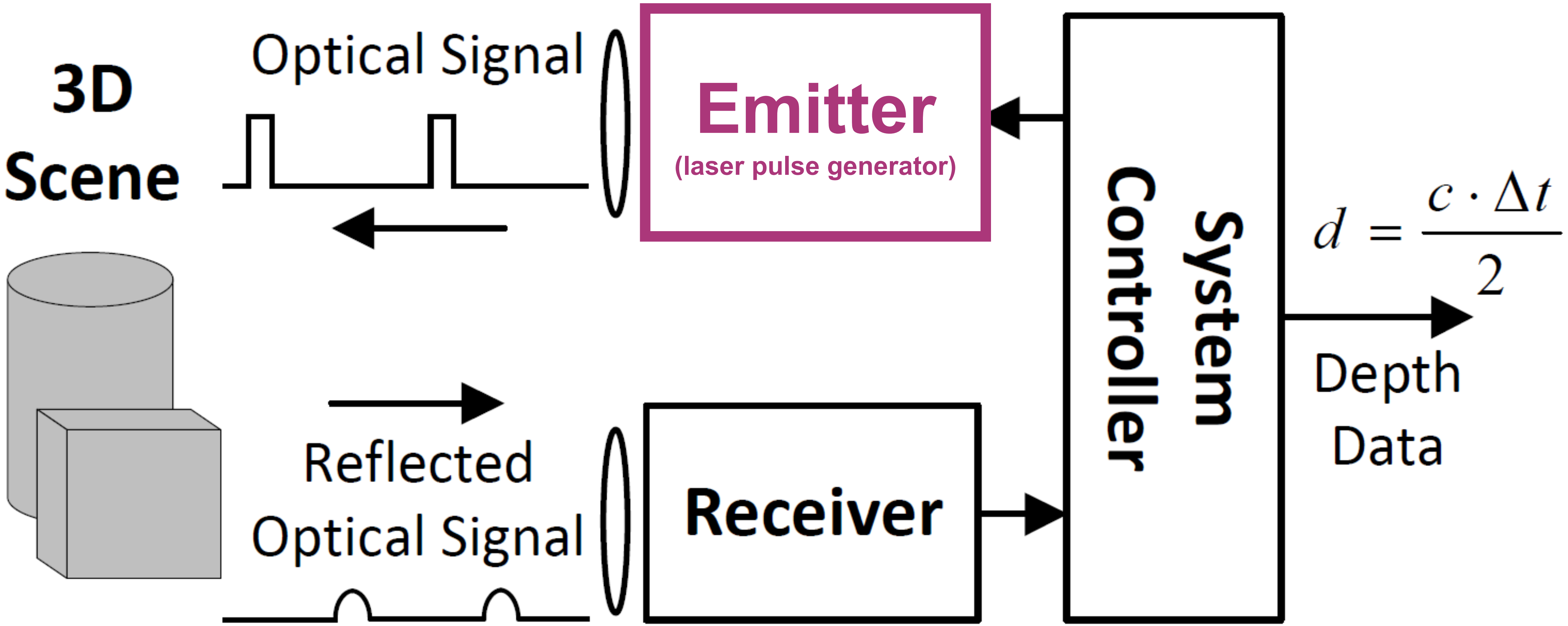
Autonomous EVs



Delivery drones

AGVs

LiDAR system overview



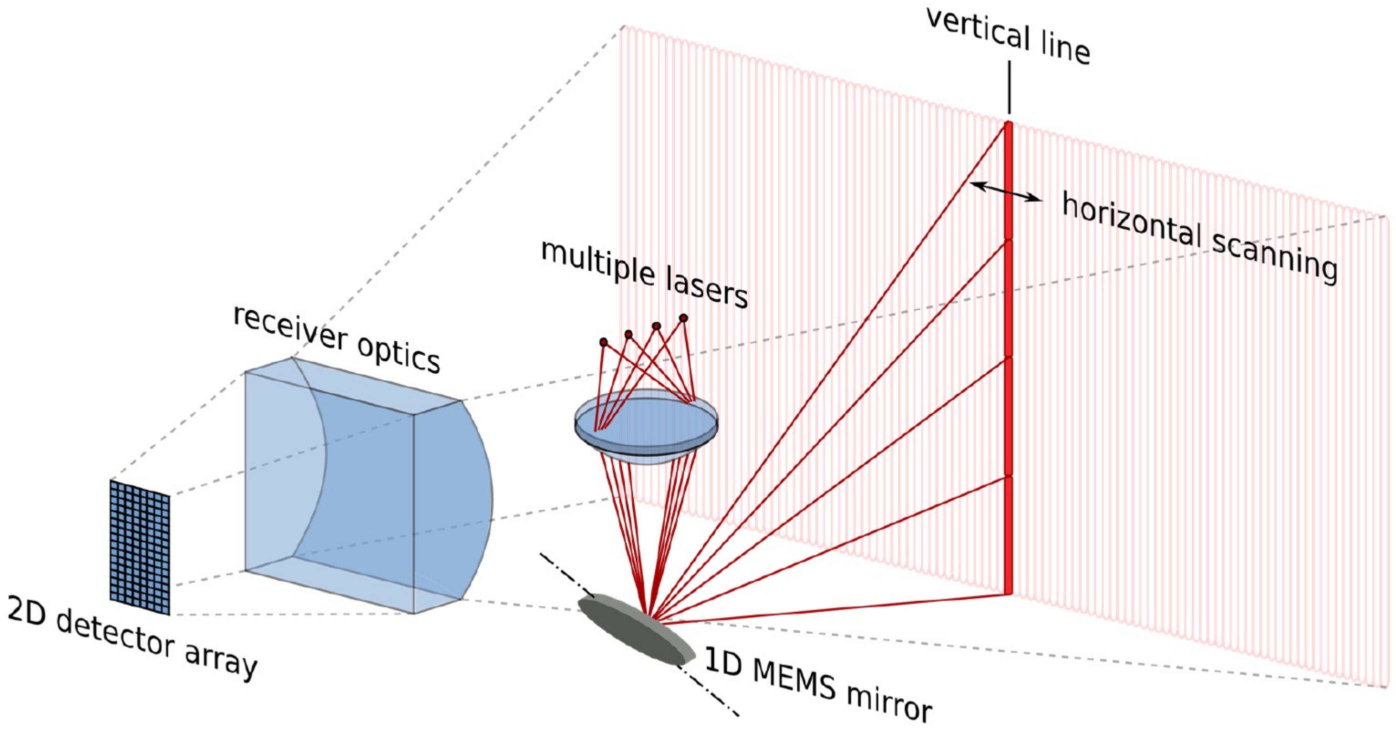
N. Druml, I. Maksymova, T. Thurner, D. van Lierup, M. Hennecke, A. Foroutan, “1D MEMS micro-scanning LiDAR,” International Conference on Sensor Device Technologies and Applications, Venice, Italy, Sept. 2018.

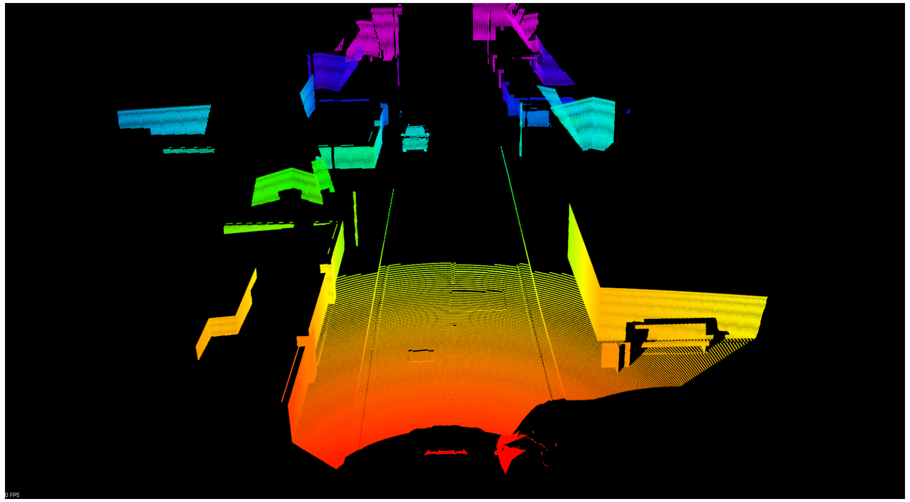
Outline

1D MEMS micro-scanning lidar system

- 8-channel laser bar w/ 320 A peak for 6 ns, detecting 16 horizontal pixels per pulse
- Horizontally scanning mirror + vertically scanning MEMS mirror

- System targets:
  - 80 m range @ 10% contrast (max. range 150 m)
  - 900 x 200 = 180k pixels/frame
  - 0.1°/pixel ➔ 10 cm @ 50 m, 15 cm @ 80 m
  - 25 frames/second





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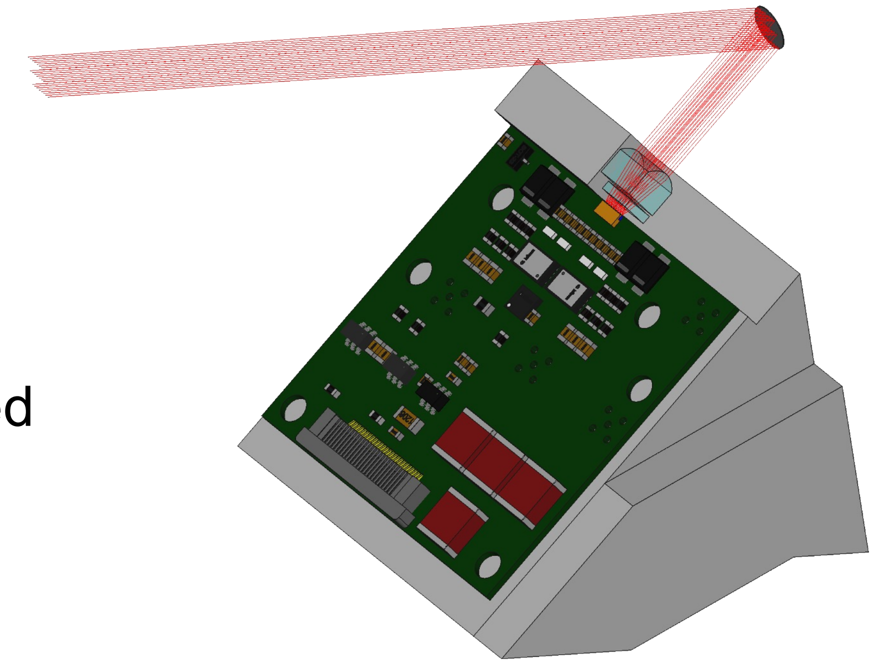
Design considerations for GaN-based laser pulse emitter

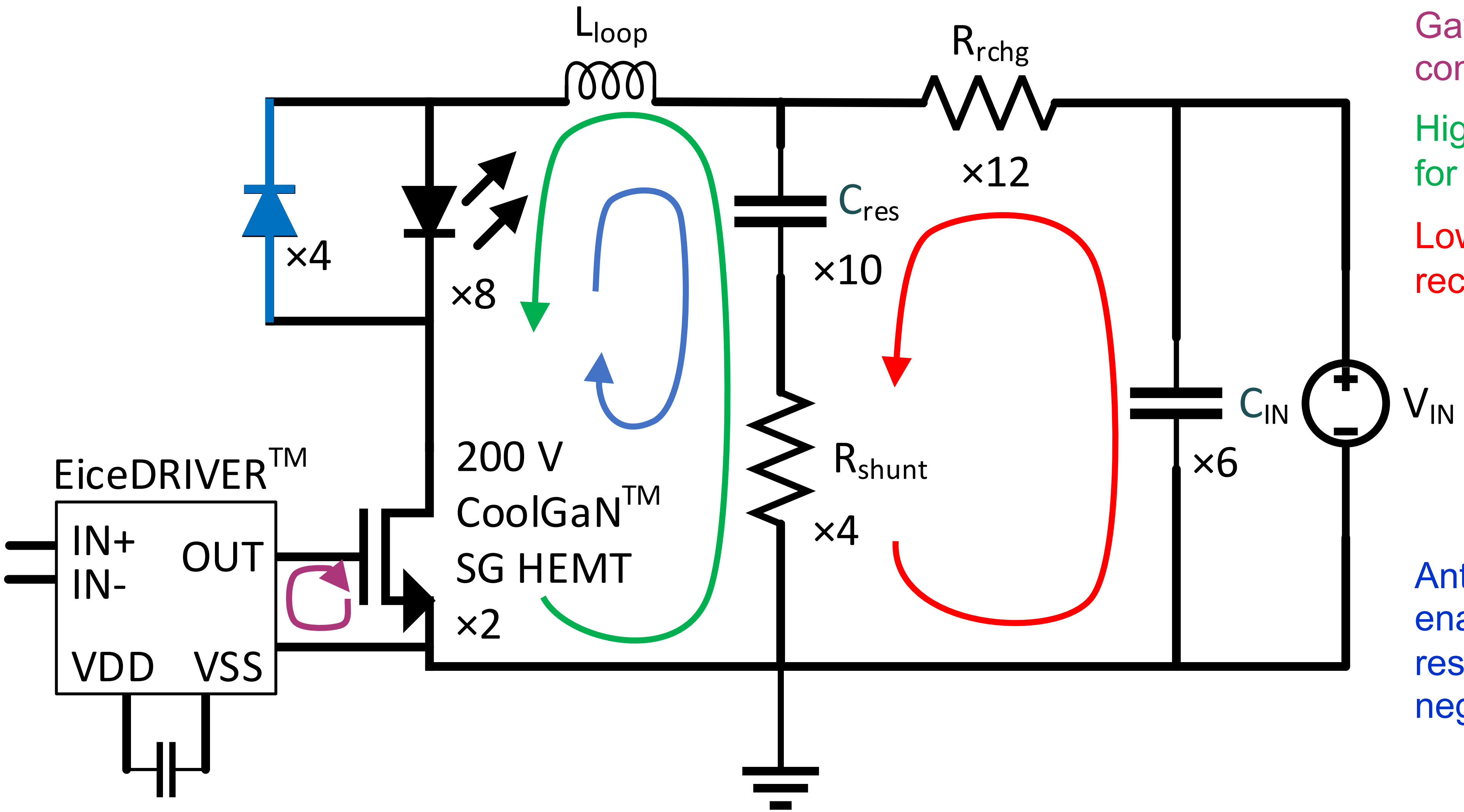
- Target is to reach I_{pk} = 320 A at T_{pulse} = 6 ns
- Resonant laser firing loop inductance is critical:
  - Includes laser diodes, GaN HEMTs, current shunts, capacitors
  - If inductance is high, V_{in} must be increased to compensate (lossy!)
- Board must also be capable to dissipate loss @ 230 kHz average
- Primary power loss / heat sources:
  - GaN HEMTs
  - Laser diodes
  - Recharge resistors
- Sensing & communication:
  - Must properly receive input signal from control board
  - Must send confirmation signal that proper pulse was emitted
  - PCB temperature sensing near to laser diode

$$I_{pk} \approx \frac{T_{pulse} \times V_{in}}{\left(\frac{2\pi}{3}\right) \times L_{Loop}}$$



Outline

Laser pulse emitter schematic



Gate loop with Kelvin source connection

High-frequency resonant loop for laser pulse current

Low-frequency loop to recharge resonant capacitors

Antiparallel Schottky diodes enable recapture of unused resonant energy during negative half-cycle

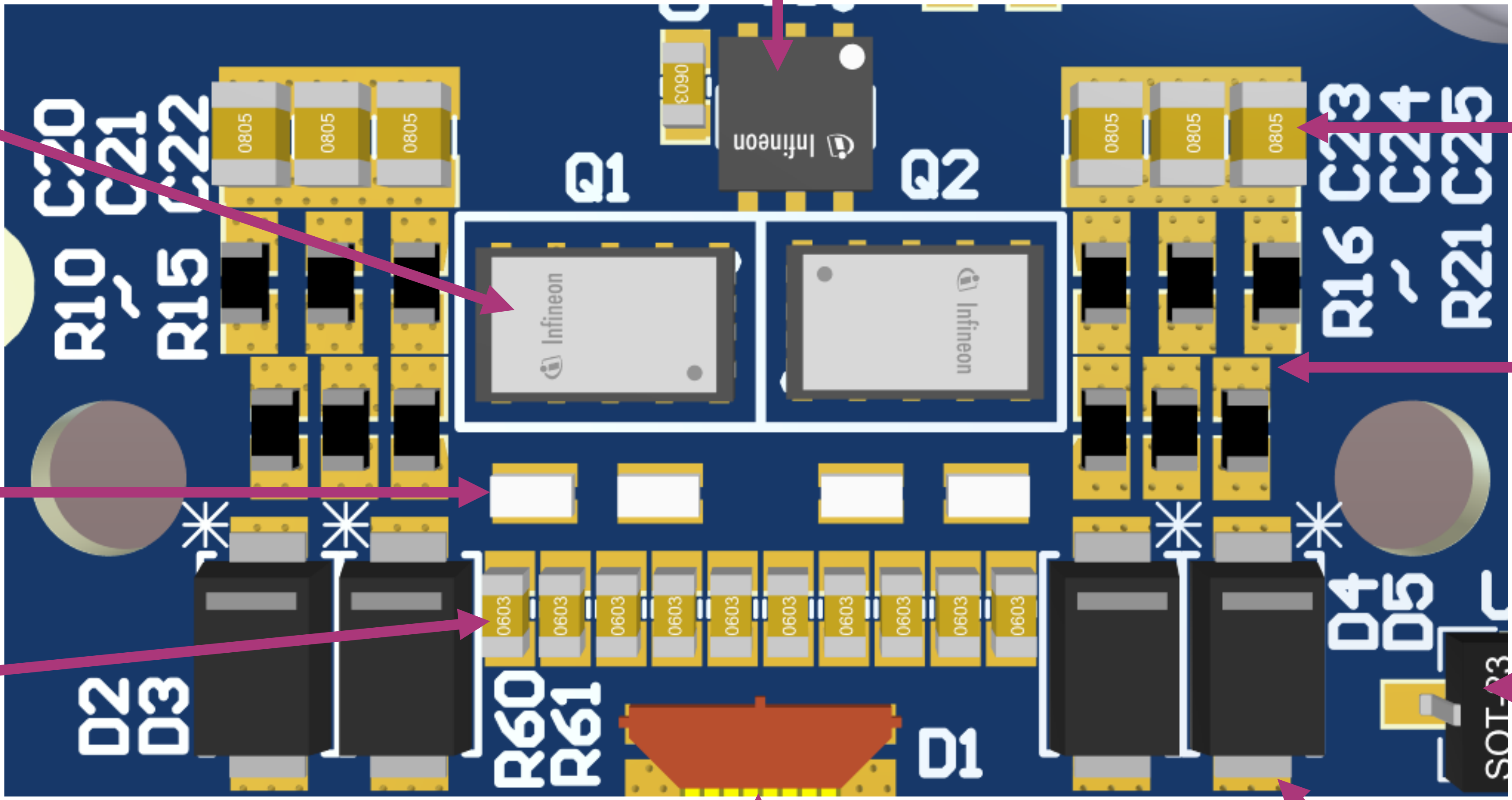
Critical PCB layout area

1EDN7512G EiceDRIVER™

200 V 10 mΩ CoolGaN™ SG HEMTs

40 mΩ current shunt resistors

Resonant capacitors



Recharge capacitors

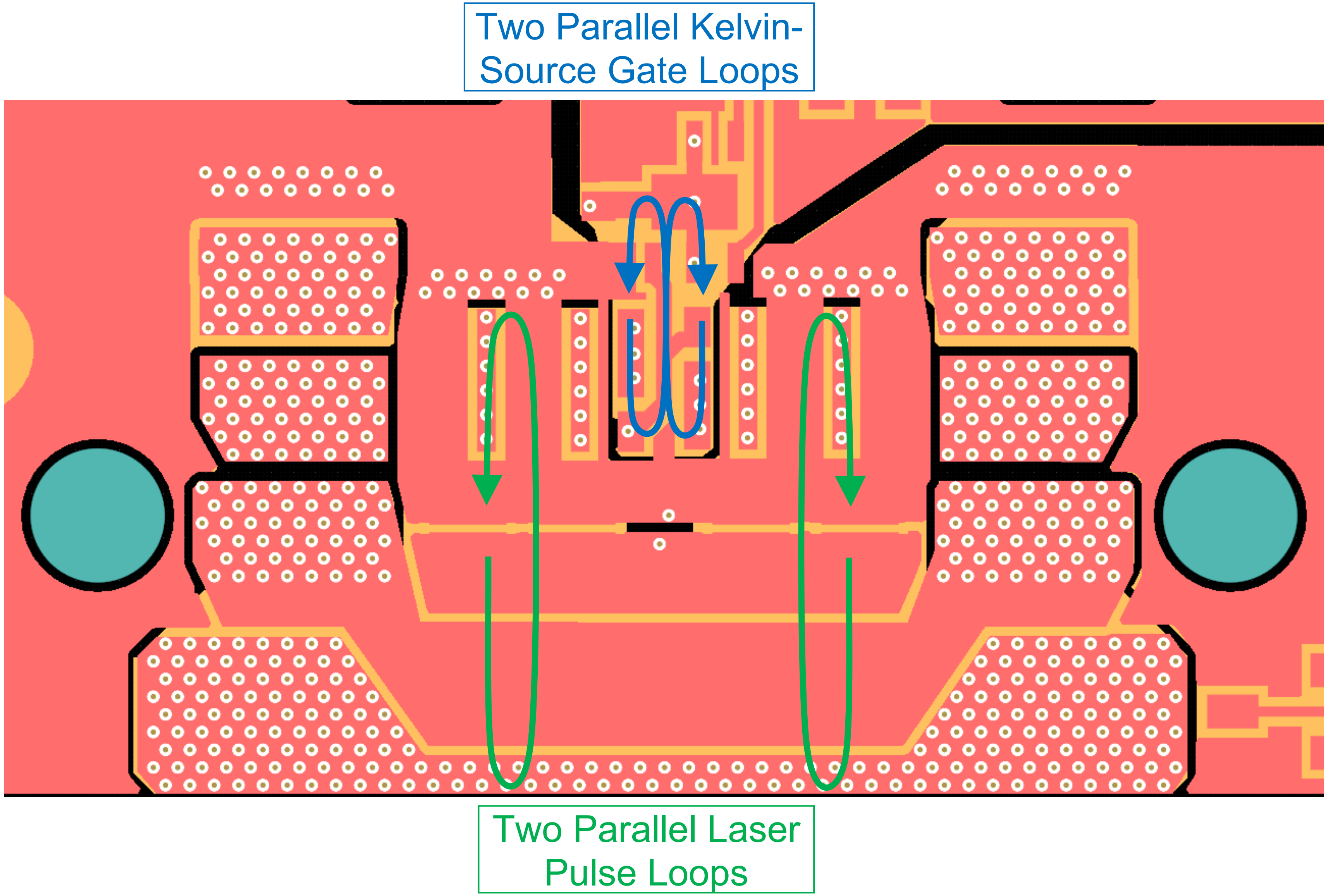
Recharge resistors

Temp. sensor

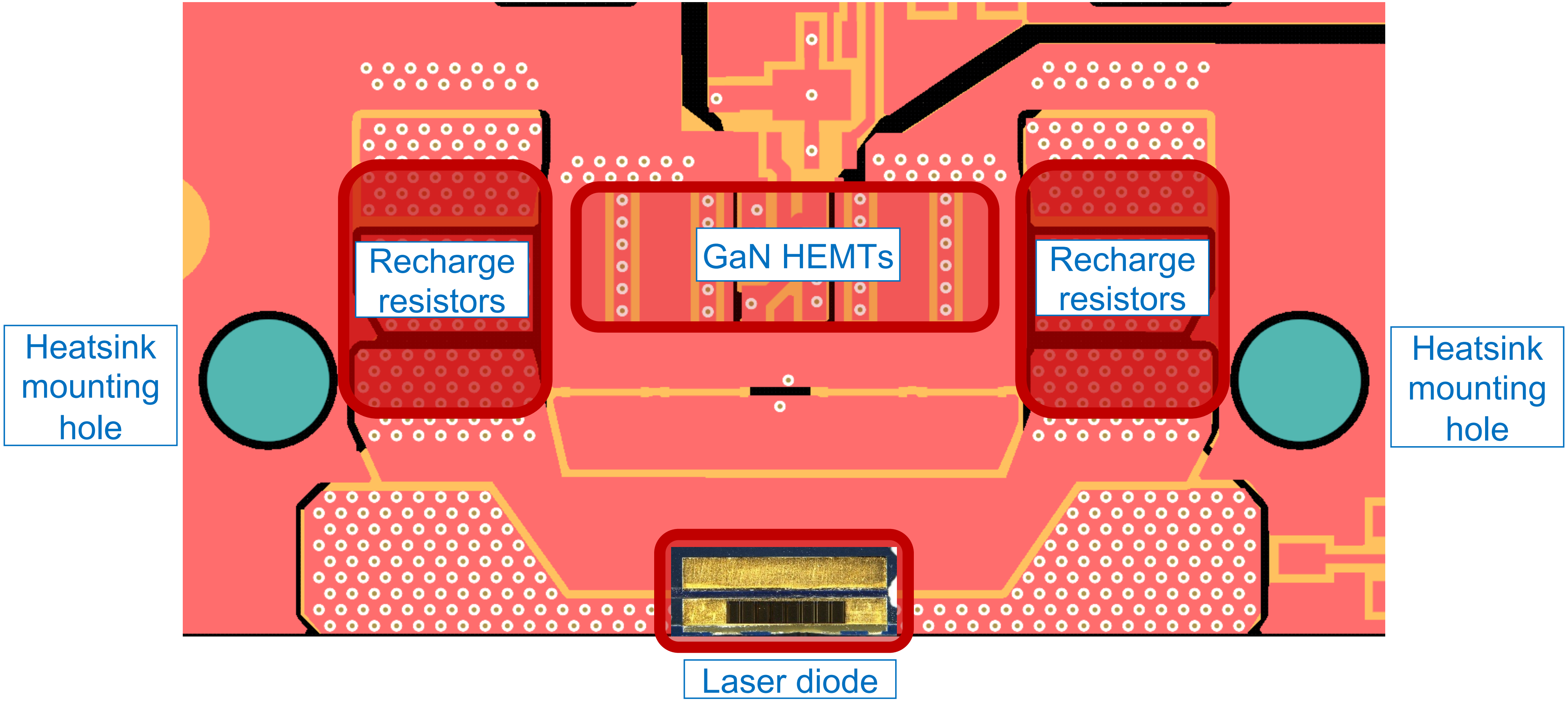
8-channel laser bar

Antiparallel Schottky diodes

Power loop inductance & gate driving circuit optimization



Thermal design

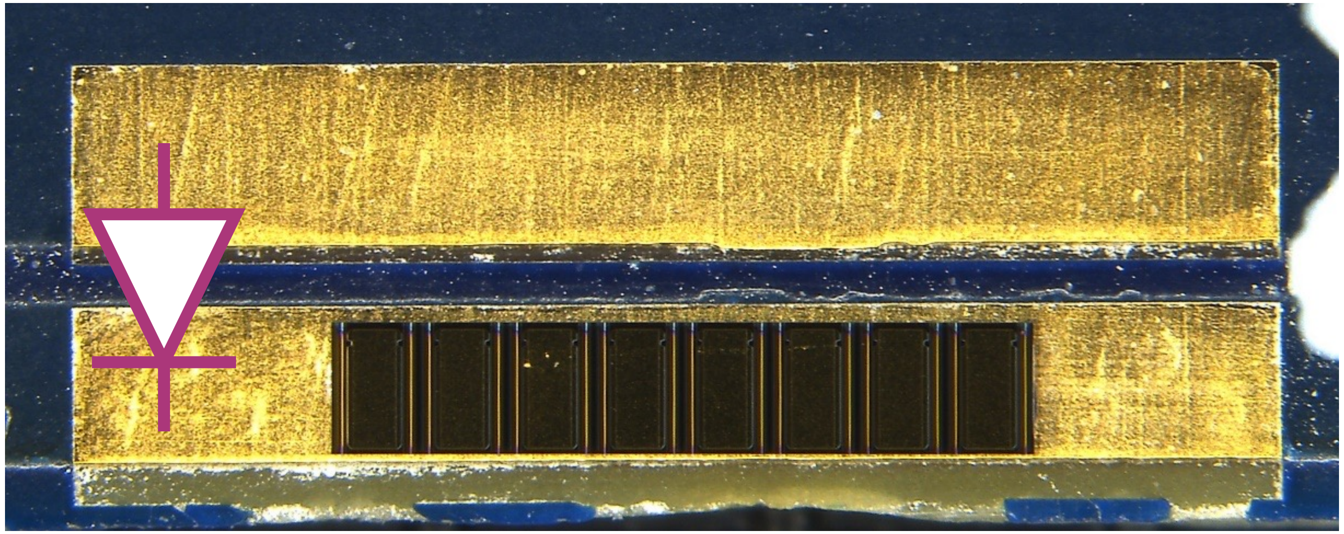


Laser diode attachment with copper clip

- Laser diodes are conventionally mounted using wire bonds
- Wire bonds avoided in this design, to reduce inductance and thermal resistance

- Copper clip approach:
  - Extremely low resonant loop inductance reduces burden on voltage supply to achieve high current in short pulse
  - Additional thermal path through anode helps to cool the laser bar & increases thermal capacitance to help ride through sweeping pulse repetition rates

Step 1: Mount laser bar cathode to PCB with conductive epoxy



Step 2: Mount copper clip to laser bar anodes & to PCB with conductive epoxy

Outline

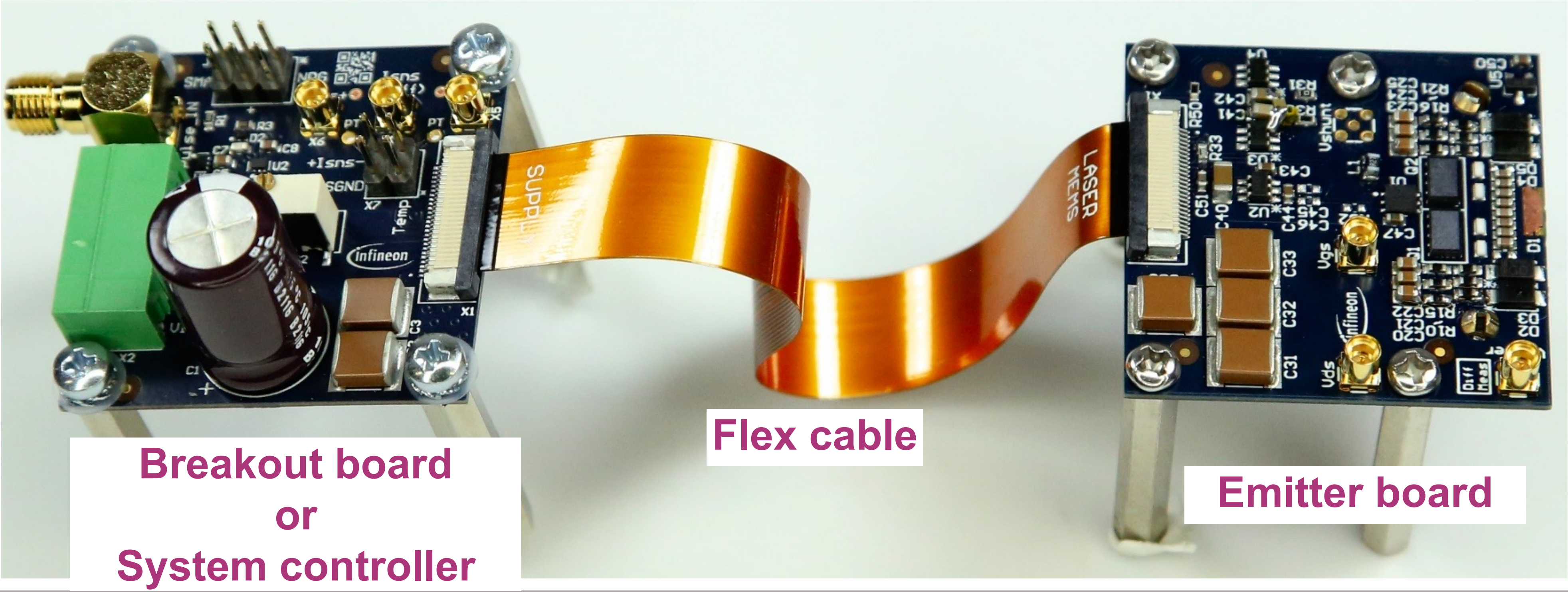
Sensing & measurement connections

Connectivity via flex cable

- Inputs:
  - V_{IN} (60~120 V)
  - V_{DD} (5 V)
  - Pulse trigger (~15 ns)
- Outputs:
  - I_{sense}
  - Temperature

Characterization measurements (on emitter board)

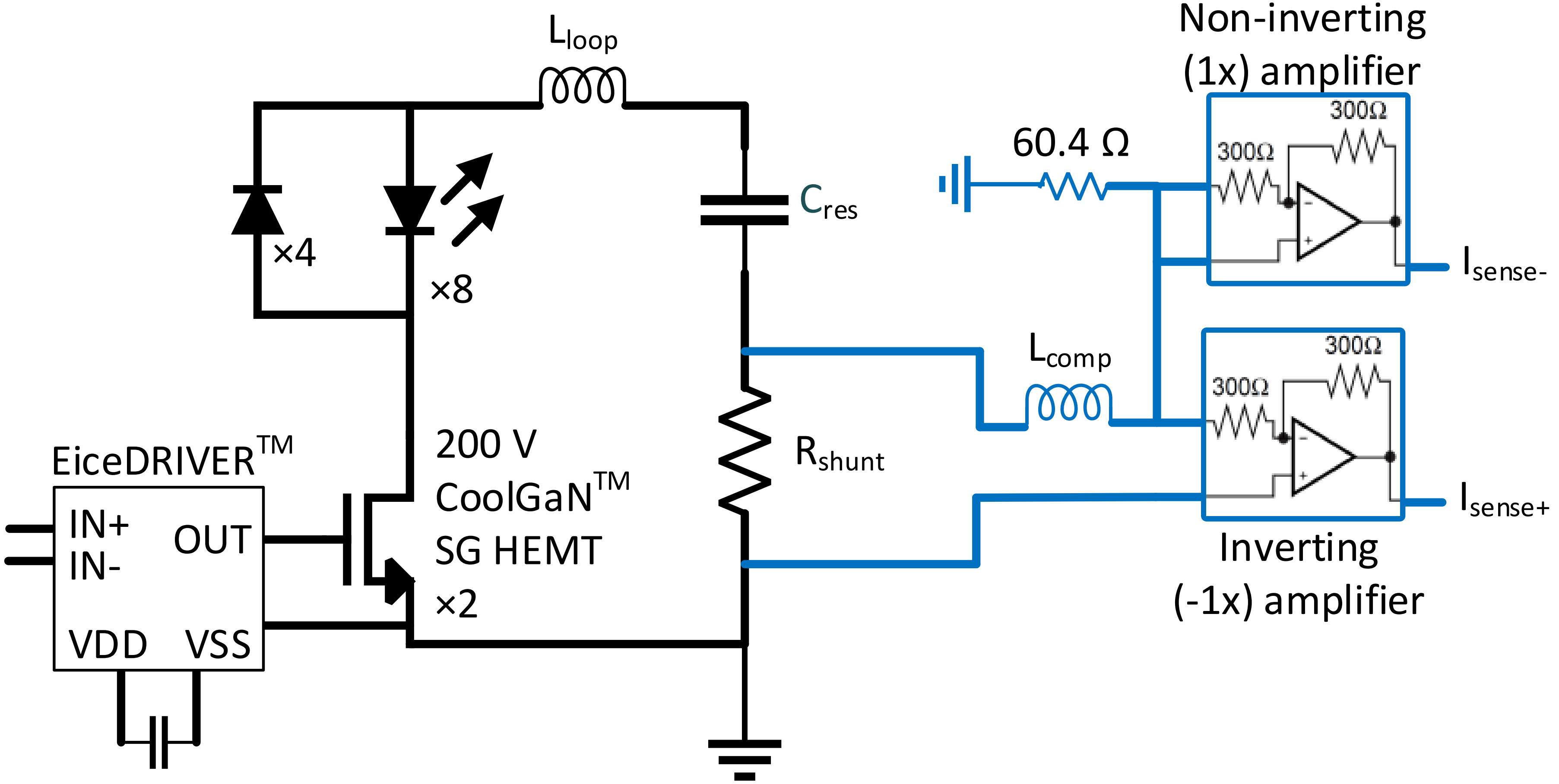
- GaN HEMT V_{DS} & V_{GS}
- V_{Laser} (differential measurement)
- V_{shunt} (raw & conditioned)



Current sensing compensation buffer circuit

$$V_{shunt} = I_{shunt}R_{shunt} + L_{shunt}\frac{dI_{shunt}}{dt}$$

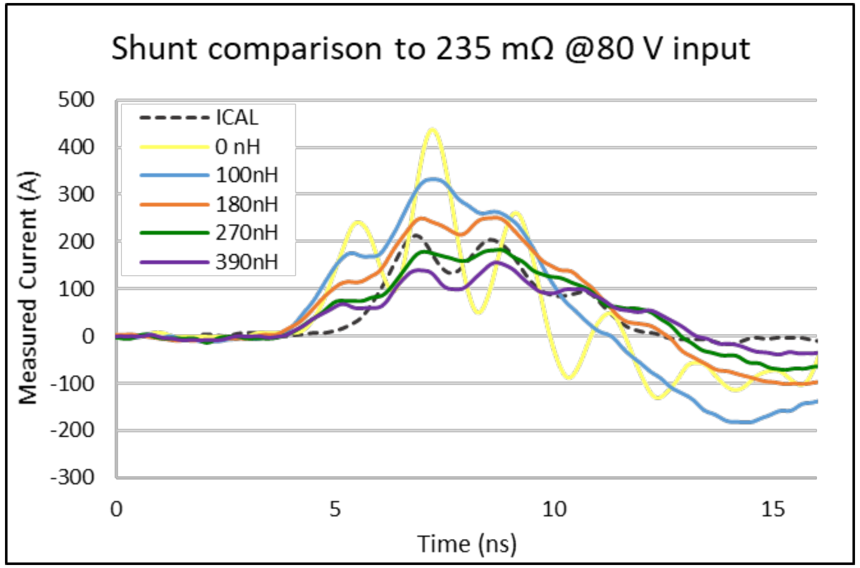
$$V_{sense} \approx V_{shunt} - L_{comp}\frac{dI_{shunt}}{dt}\left(\frac{R_{shunt}}{50\ \Omega}\right)$$

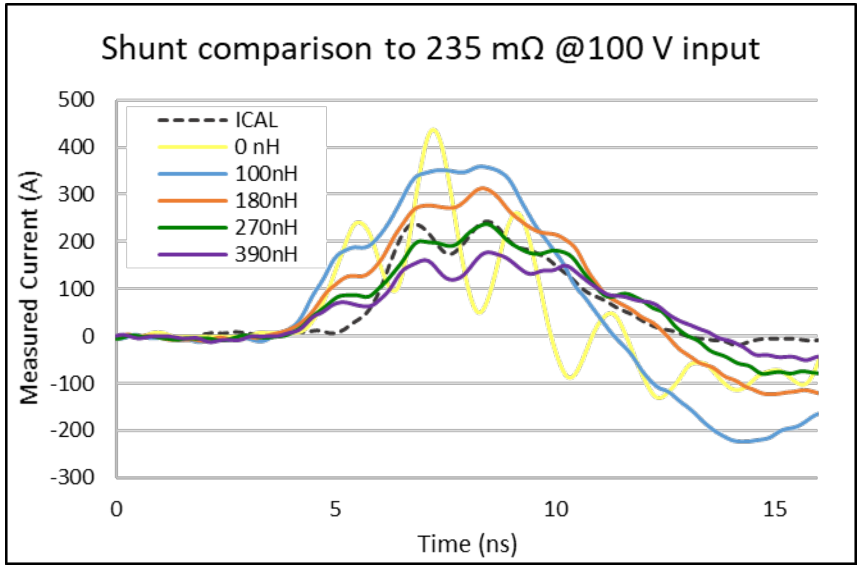


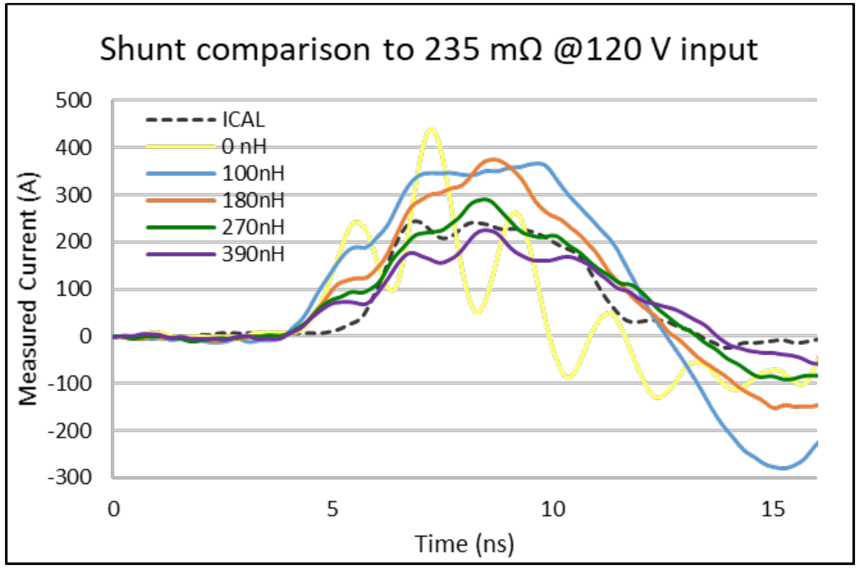
Outline

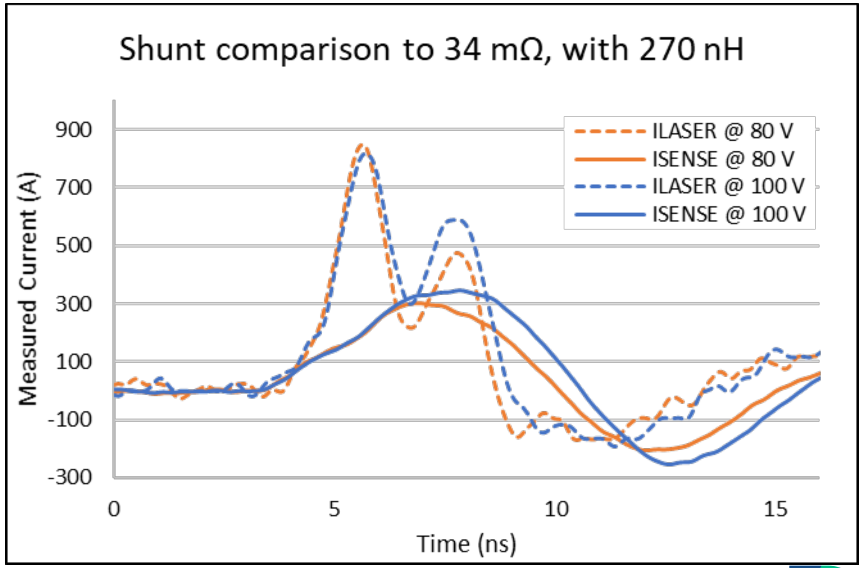
Current sensing circuit calibration: Compensating inductance evaluation with 4 ns pulse

- Current sensing circuit requires calibration against a higher bandwidth series measurement
- Laser diode footprint populated with 2× 470 mΩ parallel resistors
- Closest match to pulse width & peak found with Würth WE-KI 270 nH compensation inductor
- Remainder of testing uses laser diode equiv. 34 mΩ resistance (2×68) ➔ BW too low for current sensing





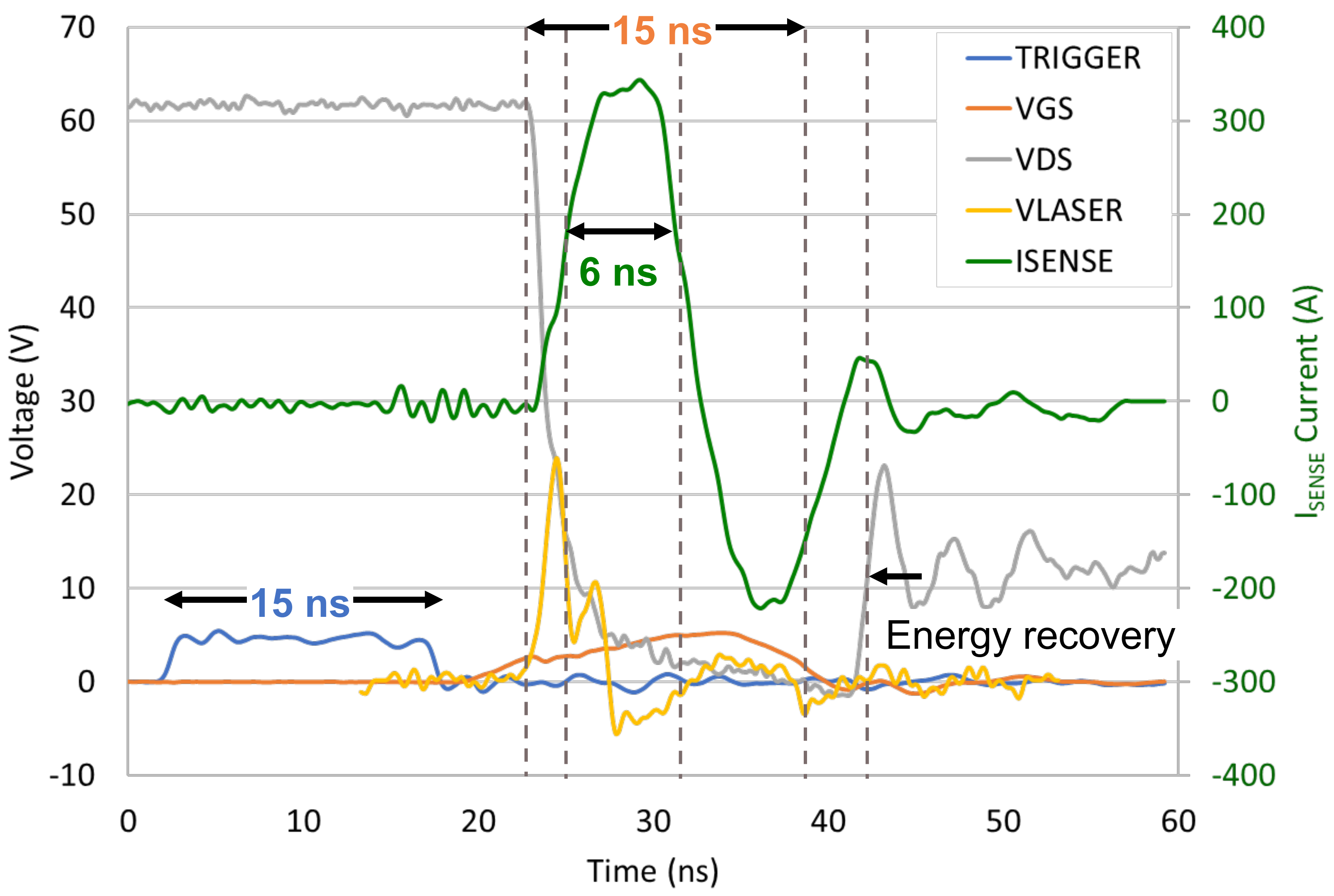




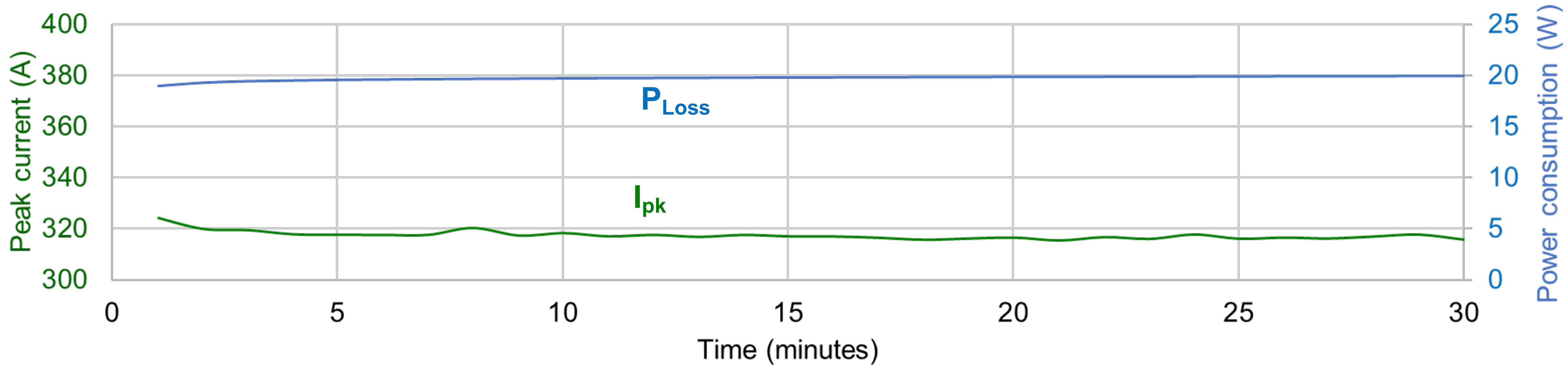
Experimental waveforms at 60 V input, 6 ns resonant pulse width

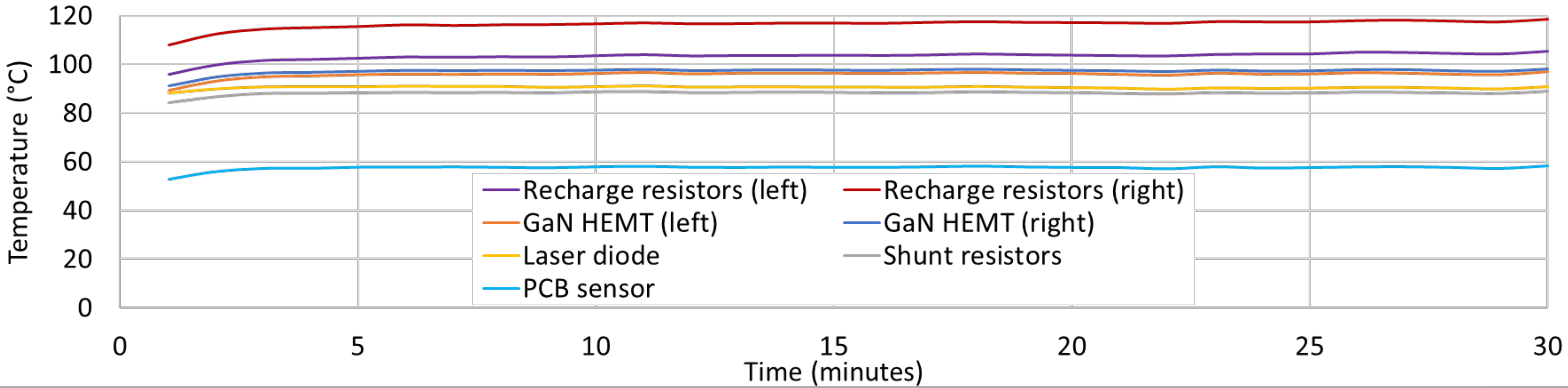
- Resonant circuit tuning:
  - Capacitance required for **6 ns** pulse ≈ **22 nF**
  - Loop inductance ≈ **400 pH**

- **15 ns** trigger/input pulse
- **15 ns** GaN HEMT on-time
- **6 ns** pulse width (half-max)
- Resonant capacitors recover **12 V** from initial 60 V after soft turn-off
- **±2 ns** input pulse margin ➔ 13~17 ns enables soft turn-off & energy recovery



Evaluation of emitter performance in steady-state operation @ 60 V input, 230 kHz





Outline

Conclusions & future work

- Laser emitter / pulse generator board achieves 320 A peak in 6 ns as targeted, with ample V_{IN} margin to account for higher insertion inductance of laser bar (if needed)
- New laser bar assembly with copper clip expected to achieve very low insertion inductance & improved thermal performance over conventional wire bond approach
- System integration taken into account, including thermal design, mechanical fit, current and temperature sensing, and connectivity to system controller via flex cable

Next steps:

- Re-evaluation of laser emitter with laser bar
  - New loop inductance will require resonant capacitance adjustment
  - Higher supply voltage may be needed
- Further work with iLIDS4SAM partners at SAL & RIEGL
  - Optical confirmation of pulse current measurements
  - LiDAR camera system assembly & characterization
  - Live demonstration of system planned for future IEEE conferences

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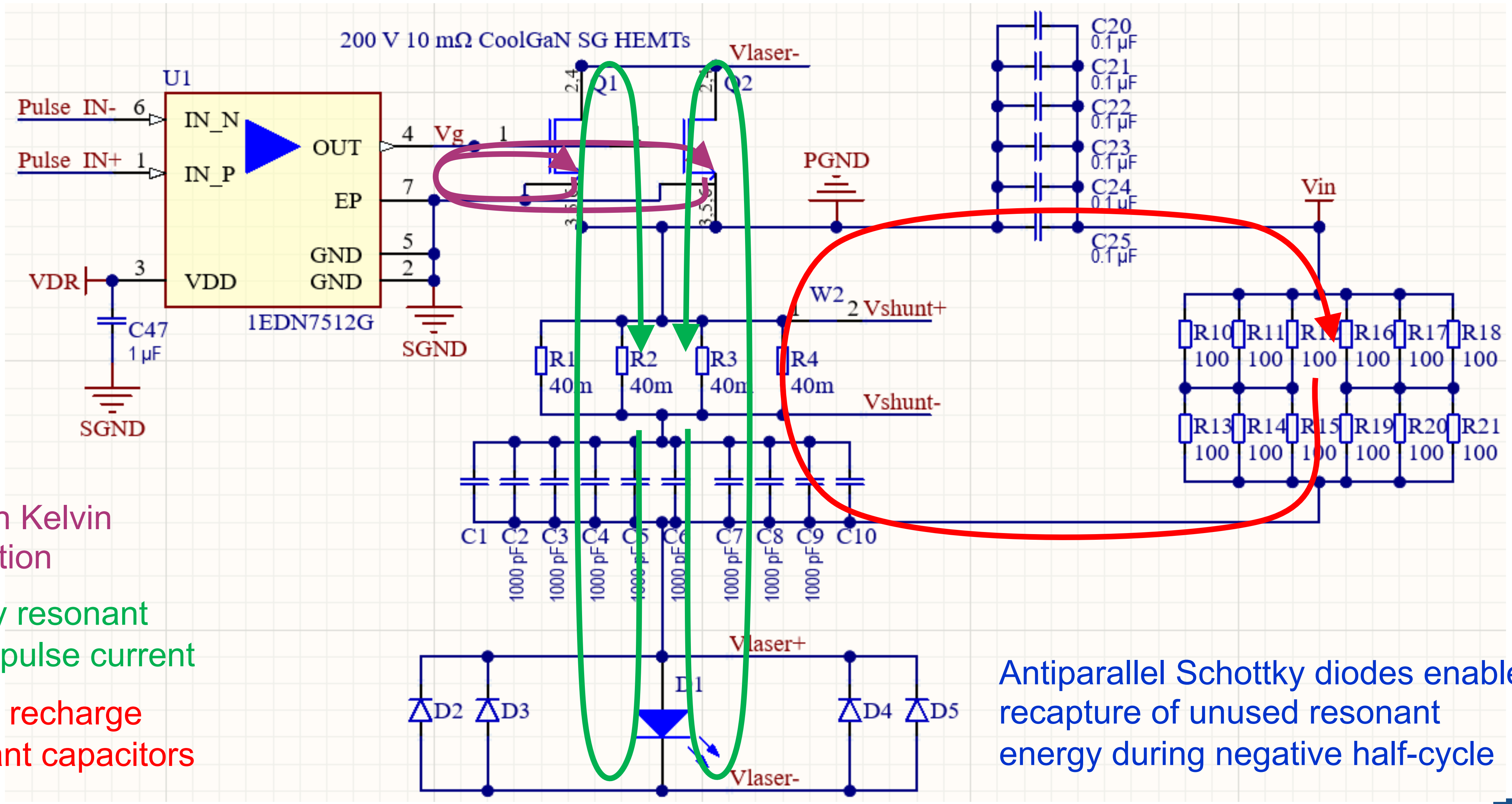
Backup slides

- Detailed emitter schematic
- Detailed current sensing compensation circuit schematic
- Heatsinking considerations
- Pulse repetition rate plot over one full mirror rotation
- Expected instantaneous power consumption of emitter over one full mirror rotation
- Experimentally measured current, power, and temperature as a function of frequency

Laser pulse emitter schematic



Gate loops with Kelvin source connection

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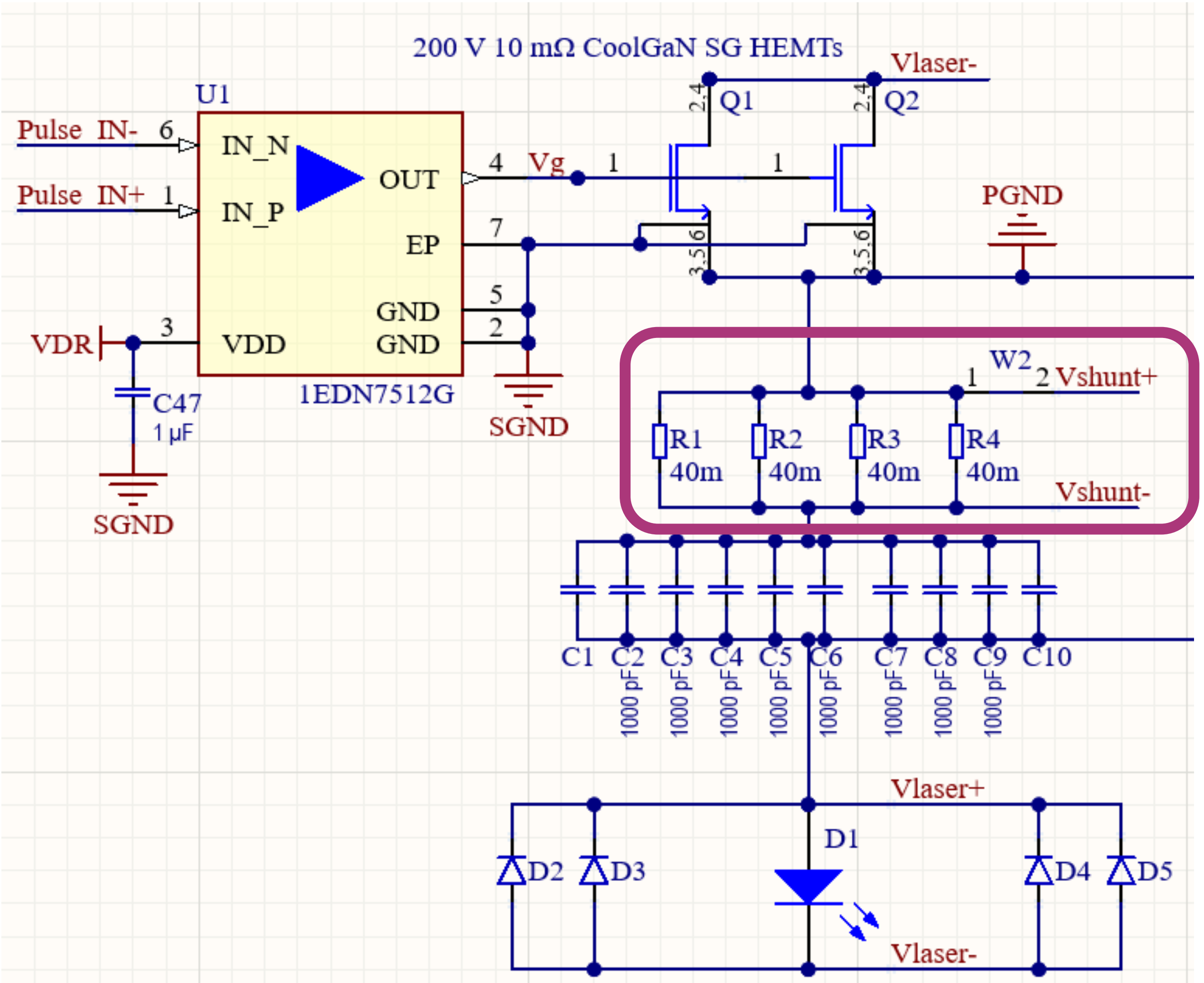
Current sensing compensation buffer circuit schematic



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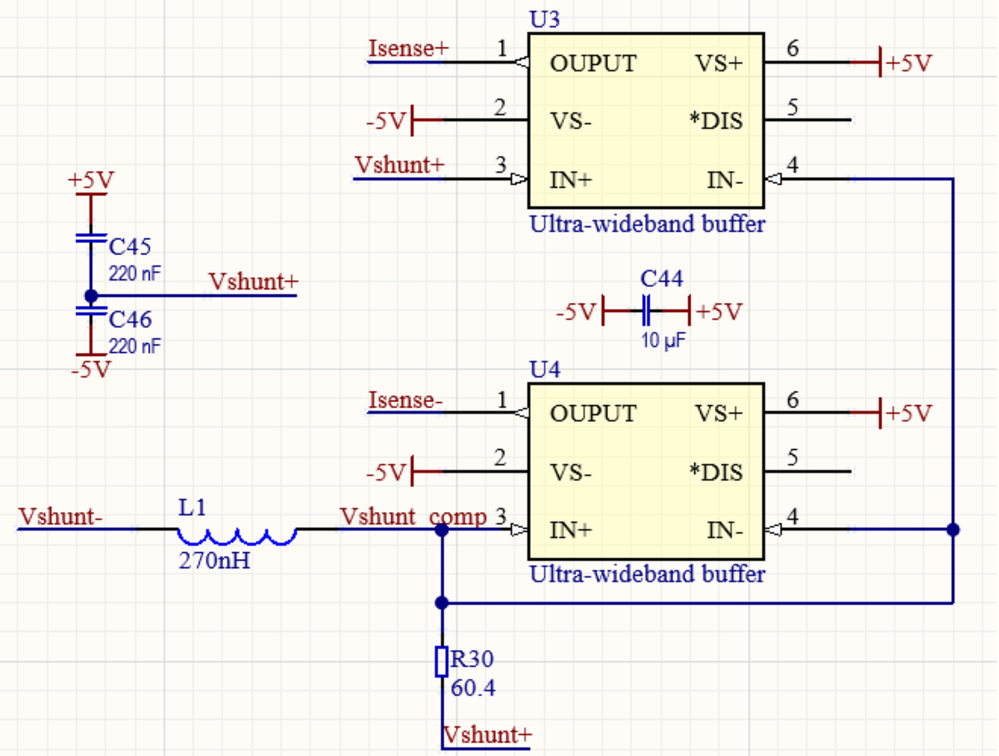
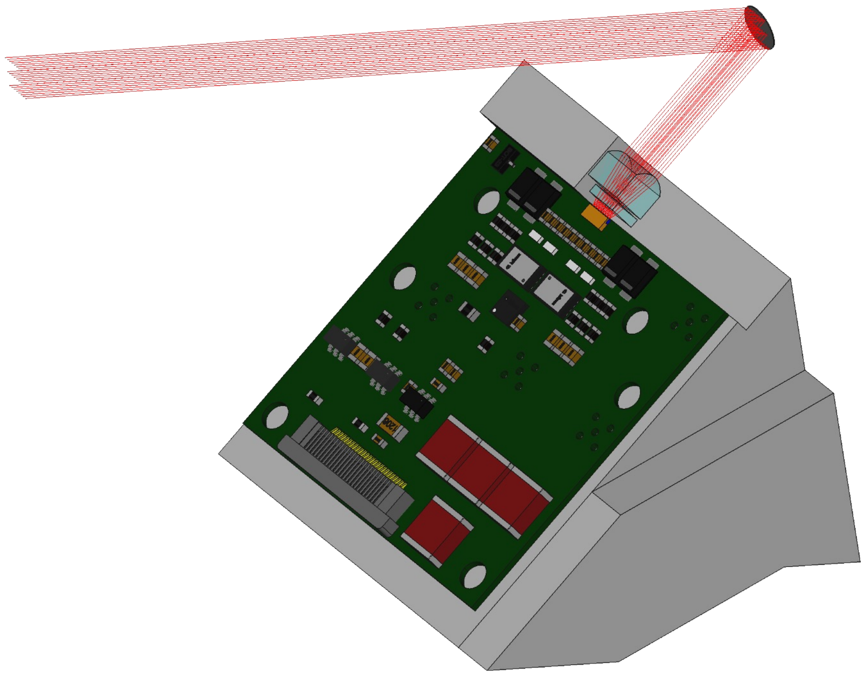


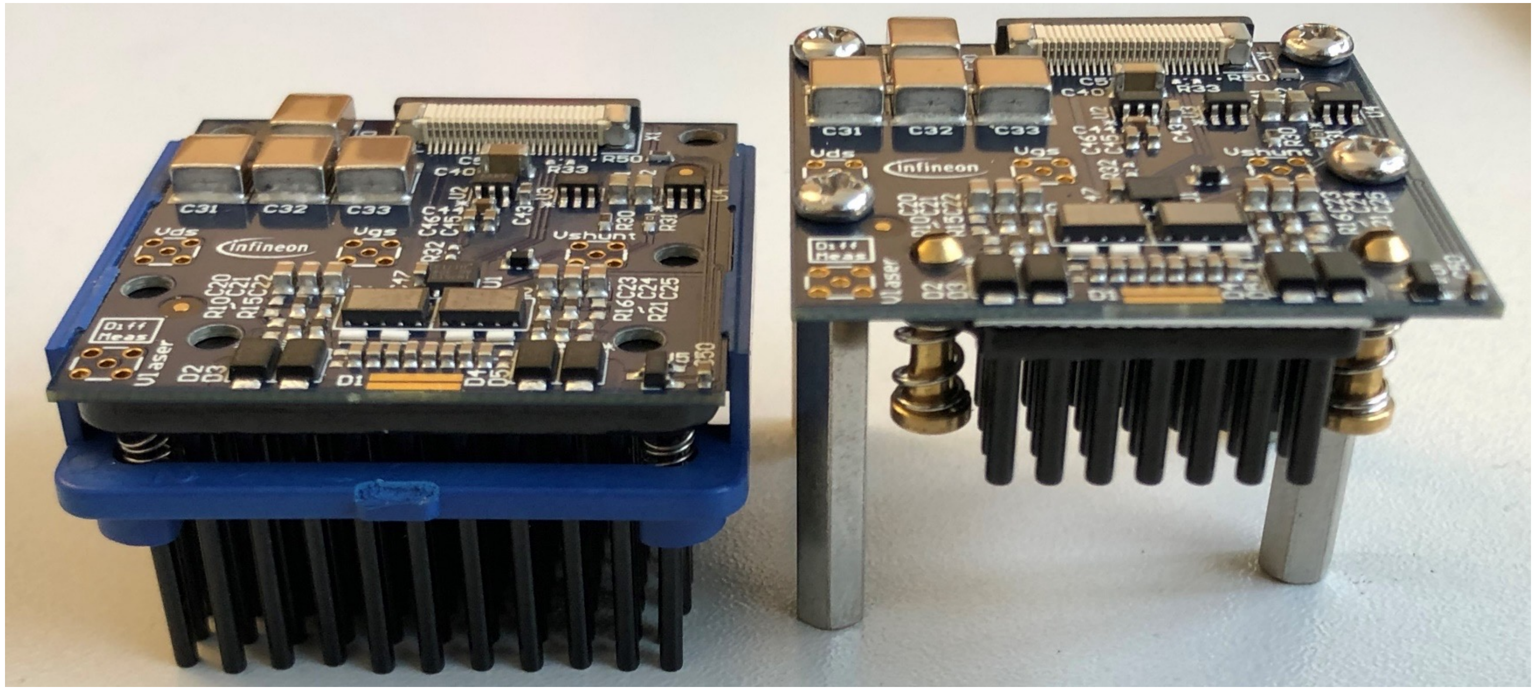
Heatsinking considerations

Final assembly in system

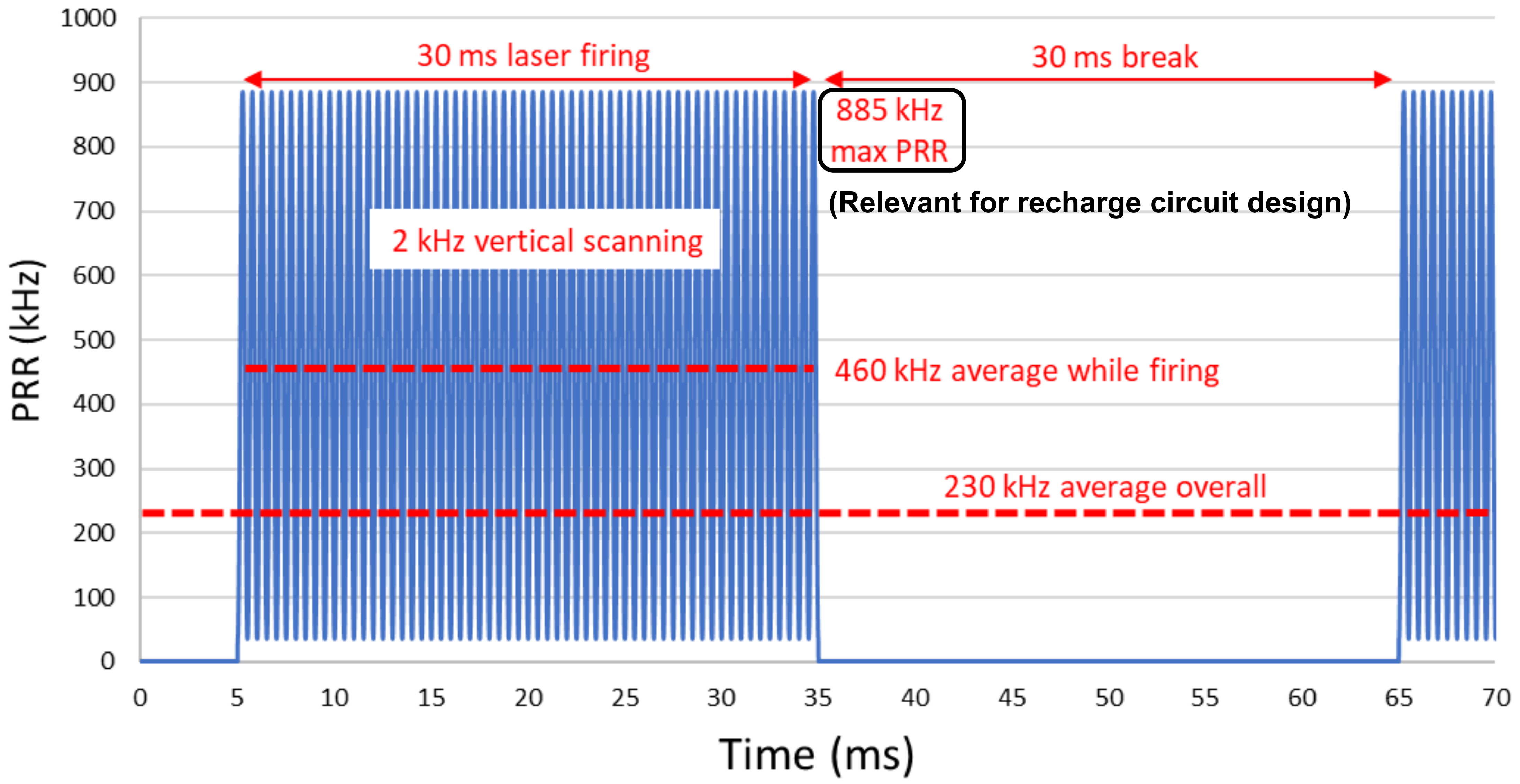


Larger heatsink used to emulate final assembly block

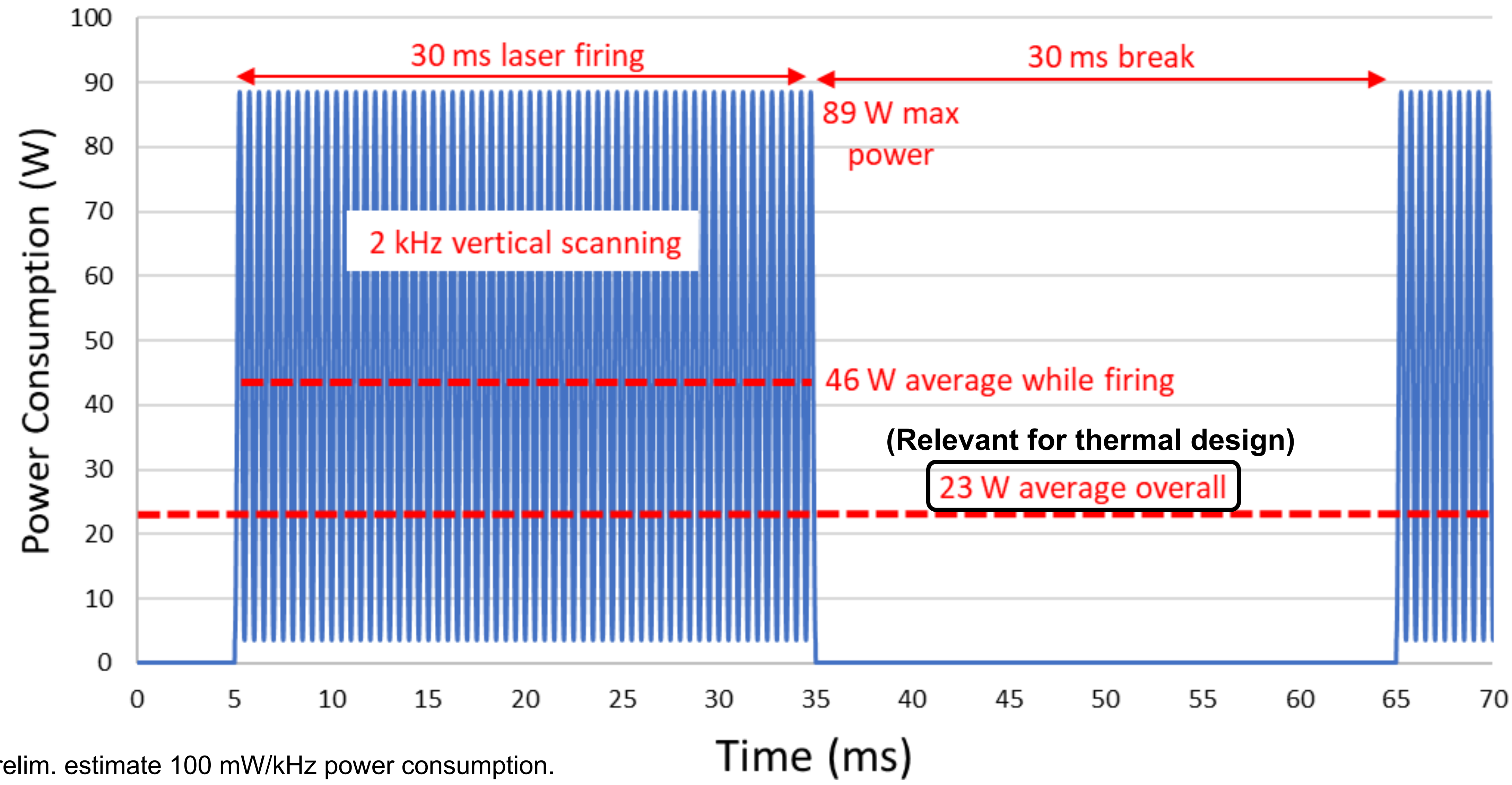
Smaller heatsink used during electrical characterization



Pulse repetition rate over one full horizontal scan



Expected power consumption over one full horizontal scan



Note: Prelim. estimate 100 mW/kHz power consumption.

Evaluation of peak current & power dissipation over frequency @ 60 V input