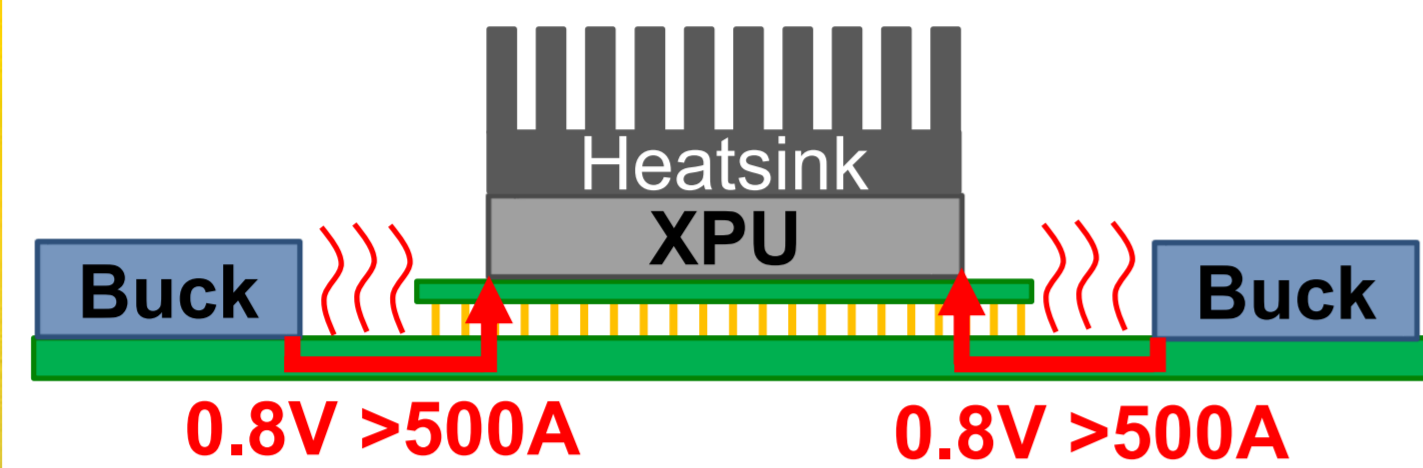
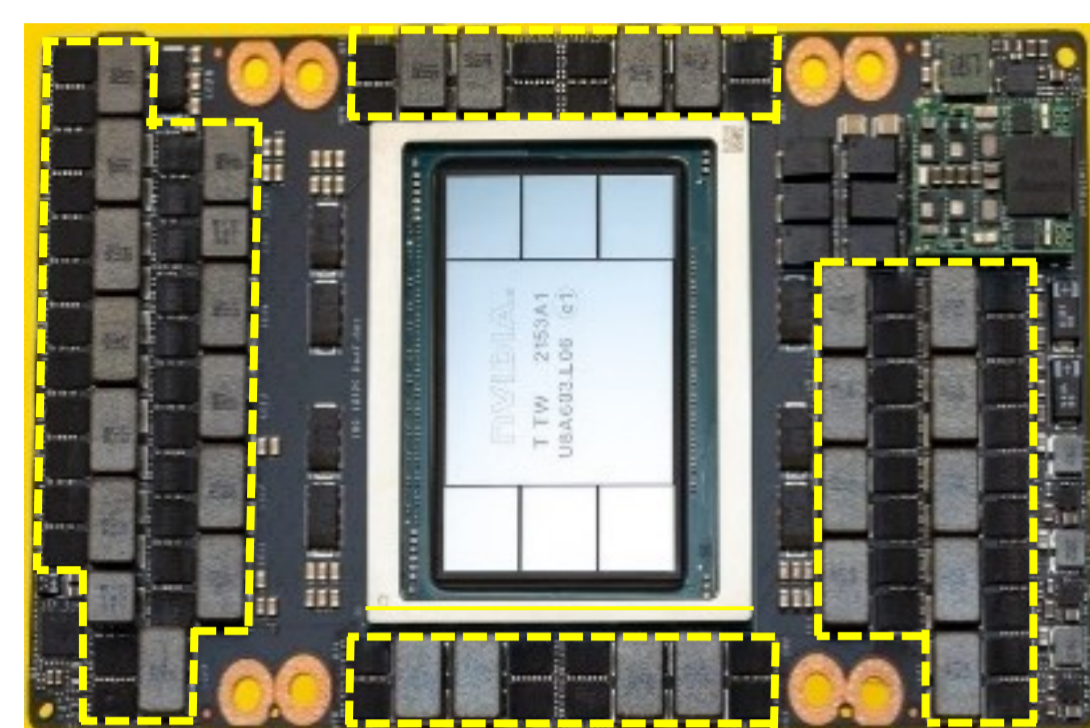


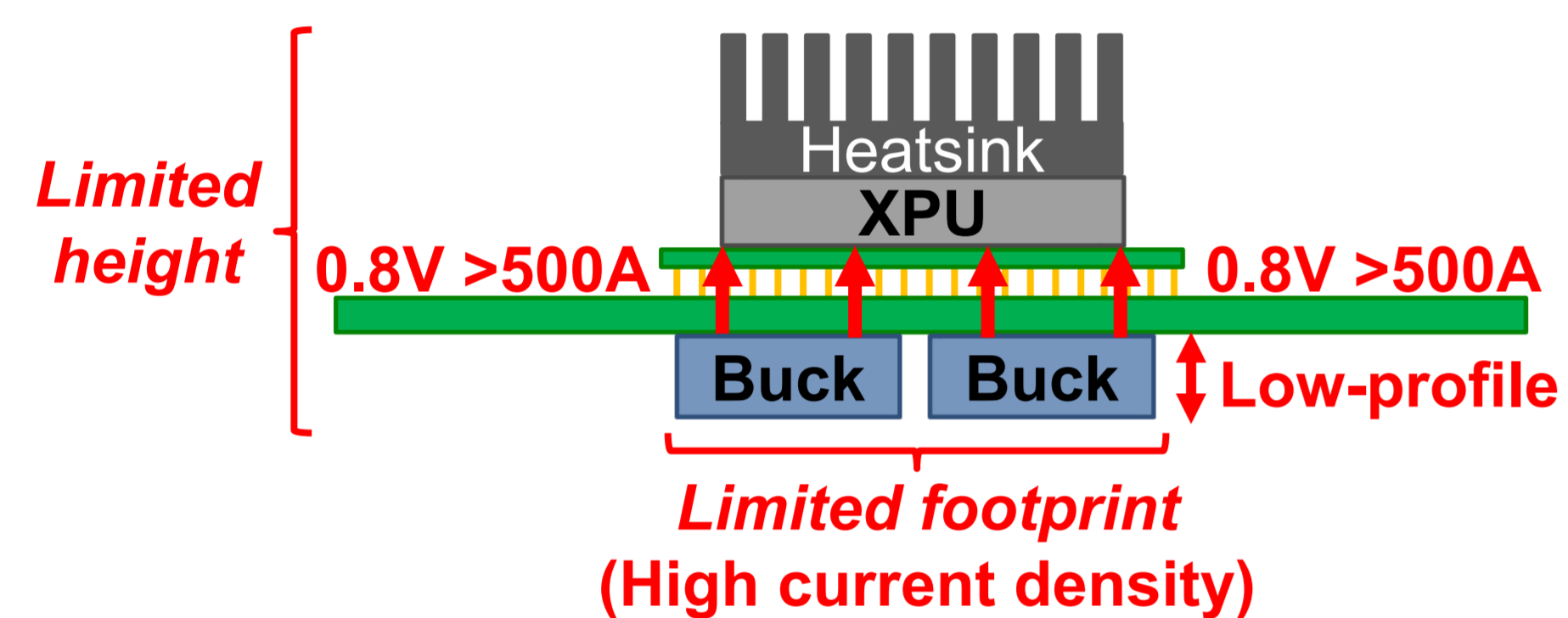
Power Delivery Architecture for Next-Generation Ultra-High-Current Processors:

State-of-the art lateral power delivery architecture:



Long PCB distance in lateral power delivery architecture causing high PDN loss and slow transient

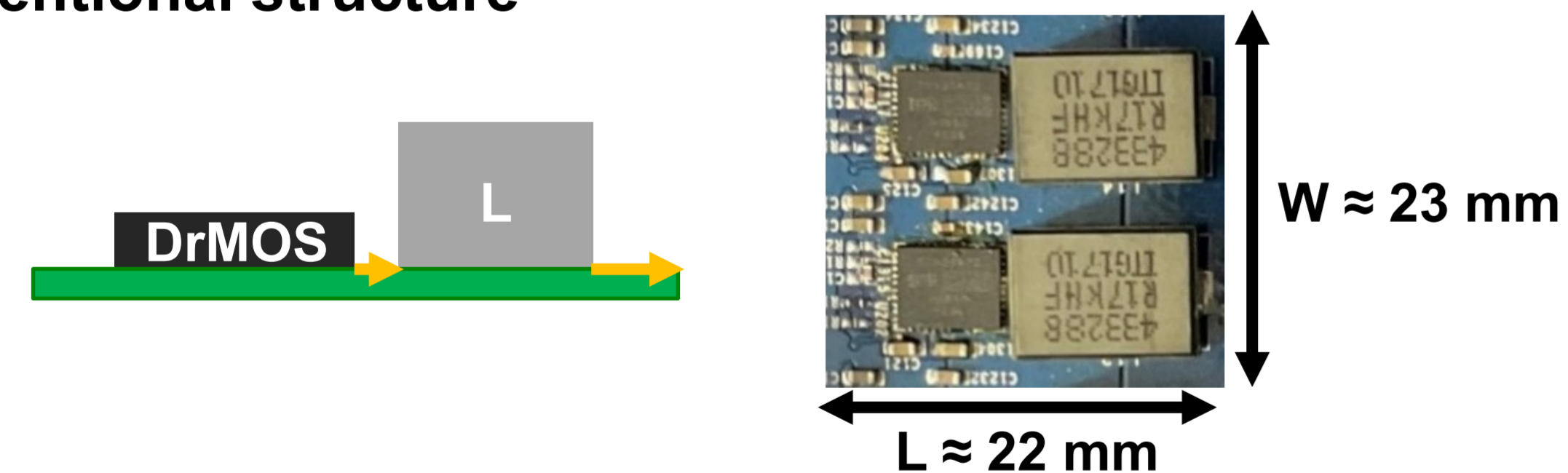
Vertical power delivery architecture:



Vertical power delivery significantly reduce the PCB distance but imposing strict size requirement for buck converter

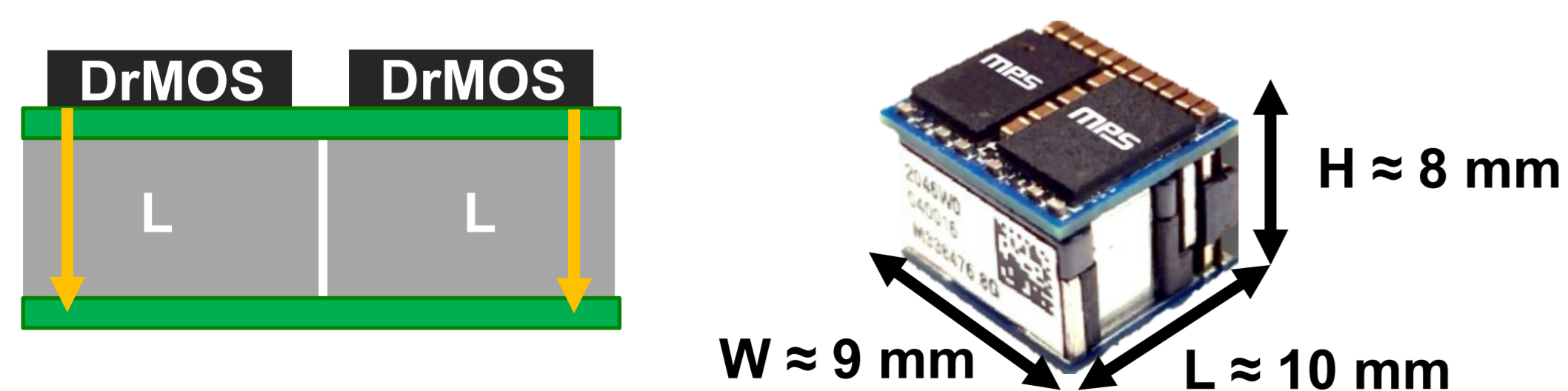
Different Voltage Regulator Module Structure:

Conventional structure



Large footprint due to lateral placement between inductor and switches

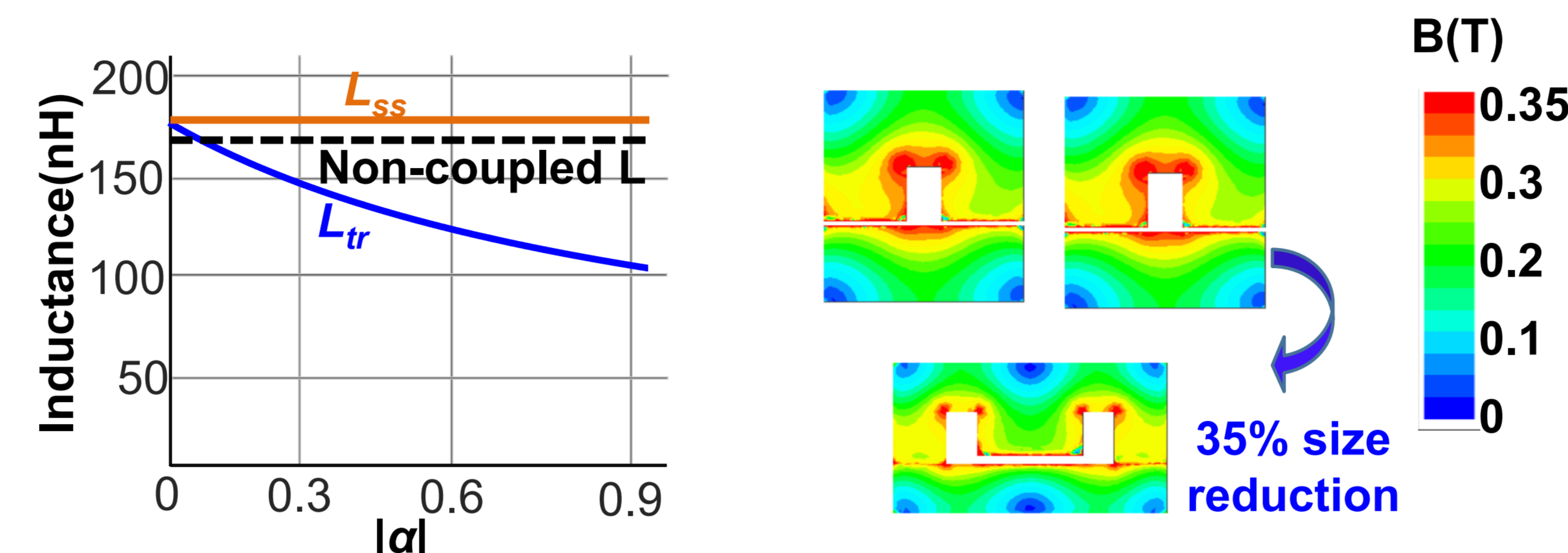
3D-stacked structure



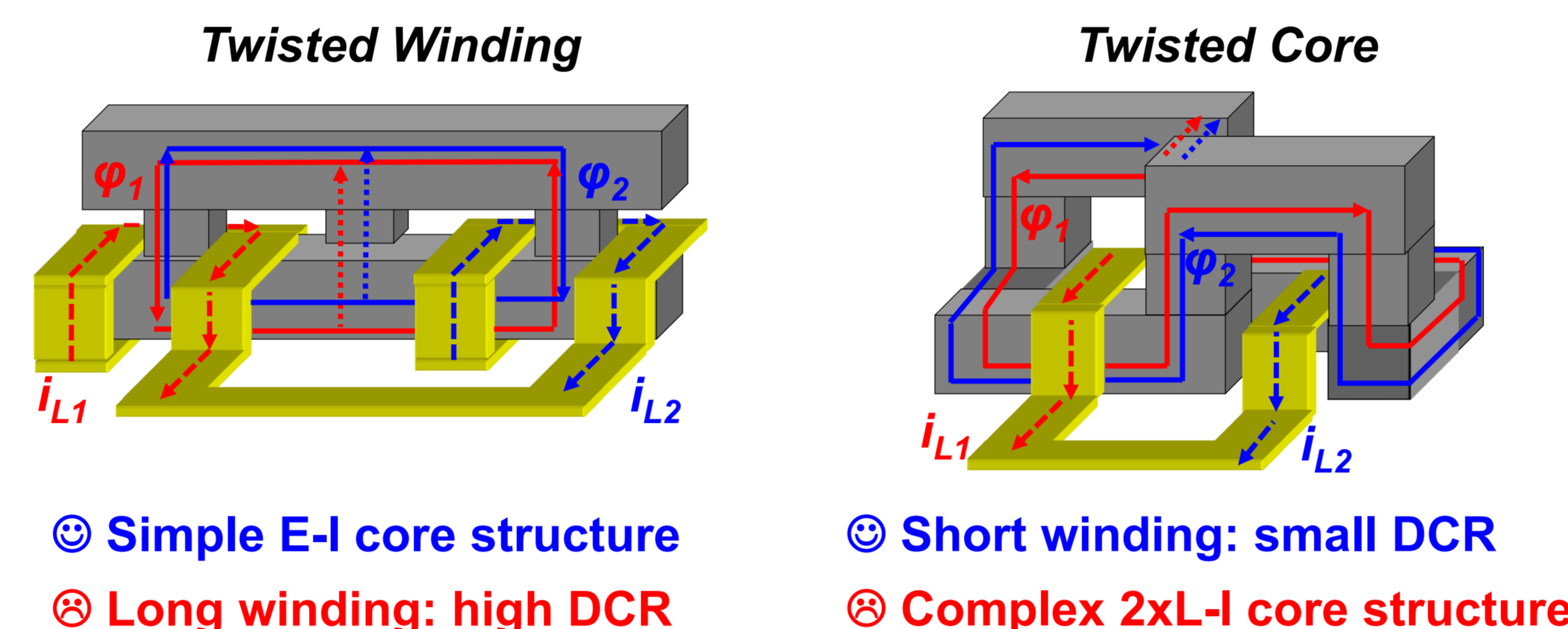
- 3D-stacked structure gives a smaller footprint.
- Tall profile due to the non-coupled inductor.

Negative Coupled Inductor:

Characteristics and benefits:

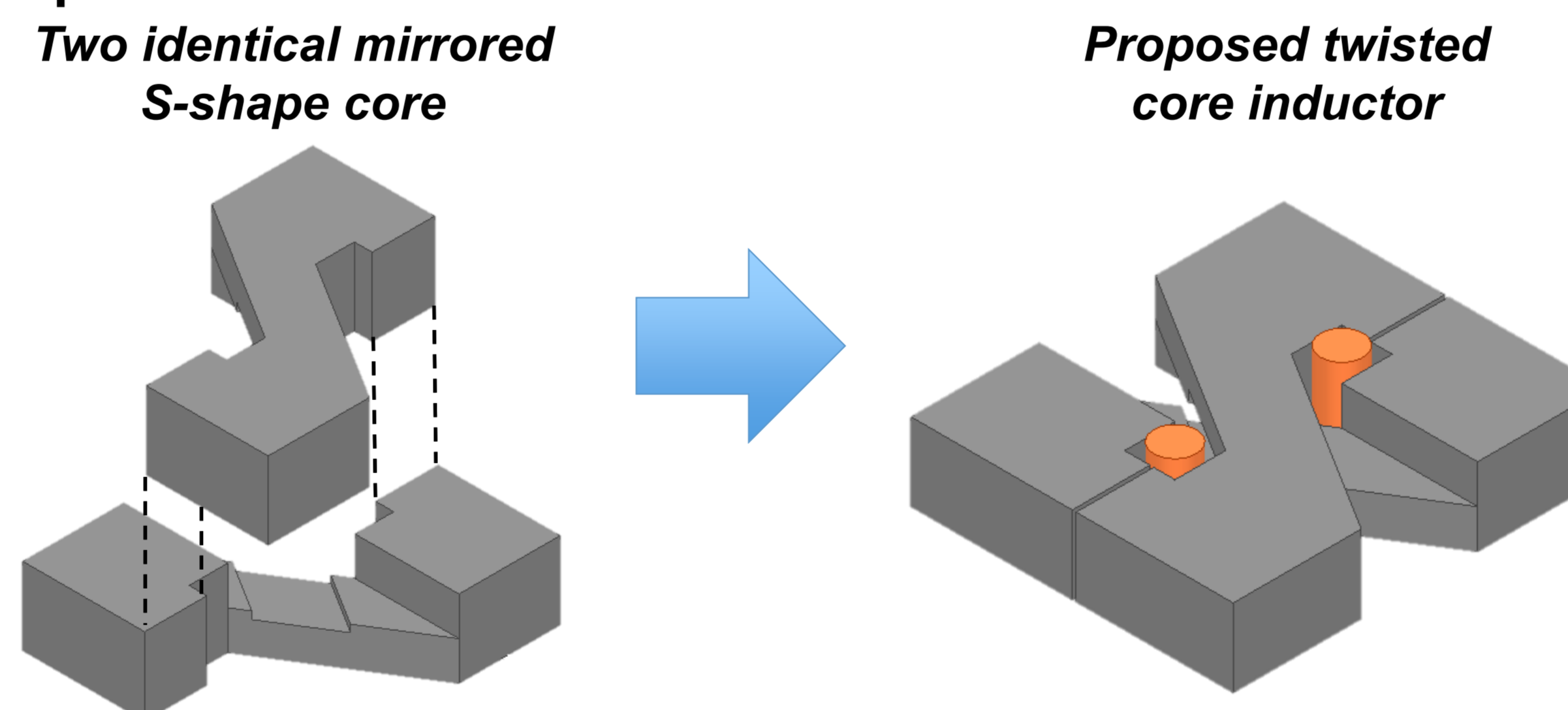


Twisted winding versus twisted core structure:



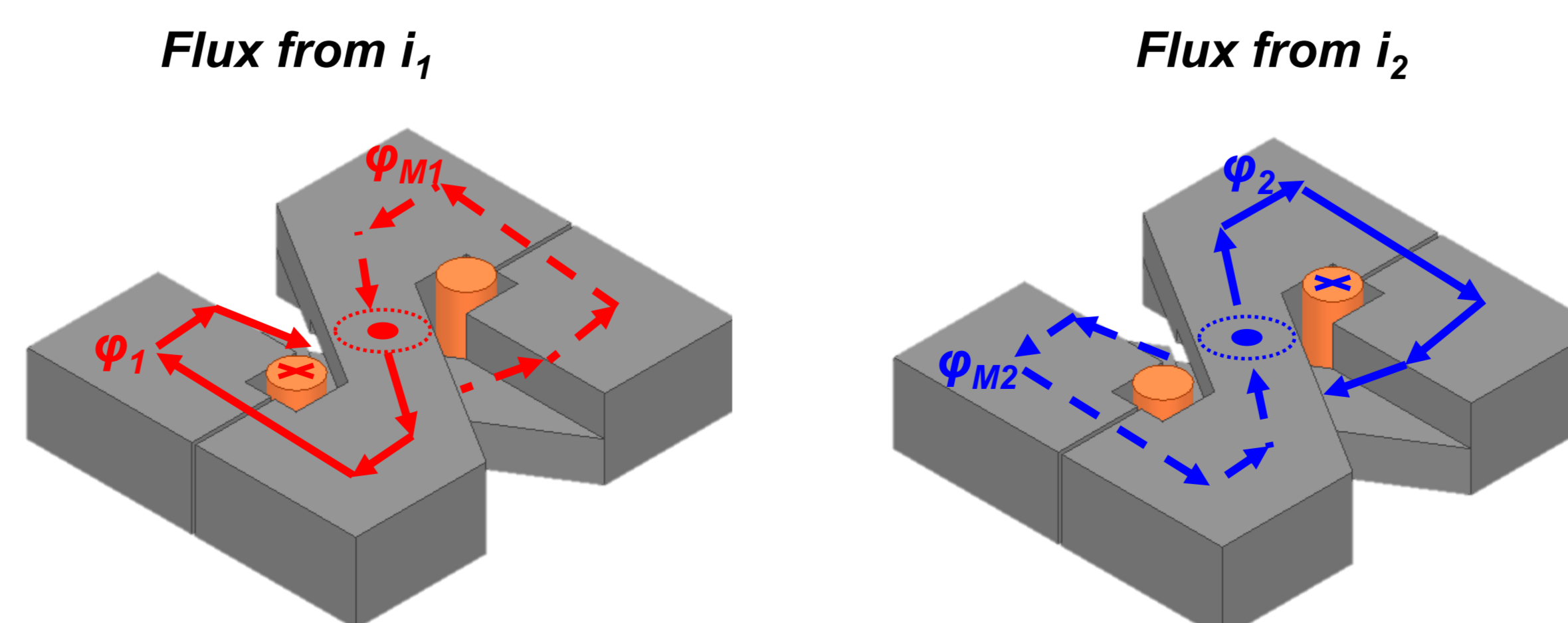
Proposed Twisted Core Negative Coupled Inductor Structure for 3D-Stacked VR Module:

Proposed twisted core inductor structure:



Single mold design and easy assembly

Flux path analysis:

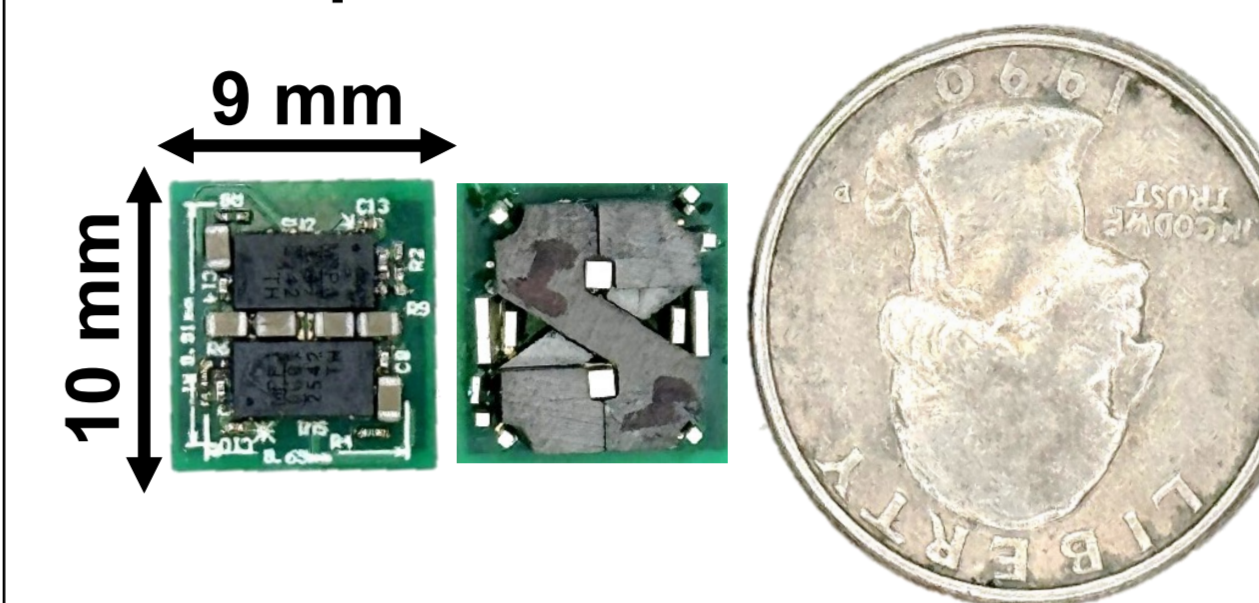


Negative coupling with the shortest winding path

Proposed High-Density 3D-Stacked VR Module

3D-Stacked Voltage Regulator Module Prototype:

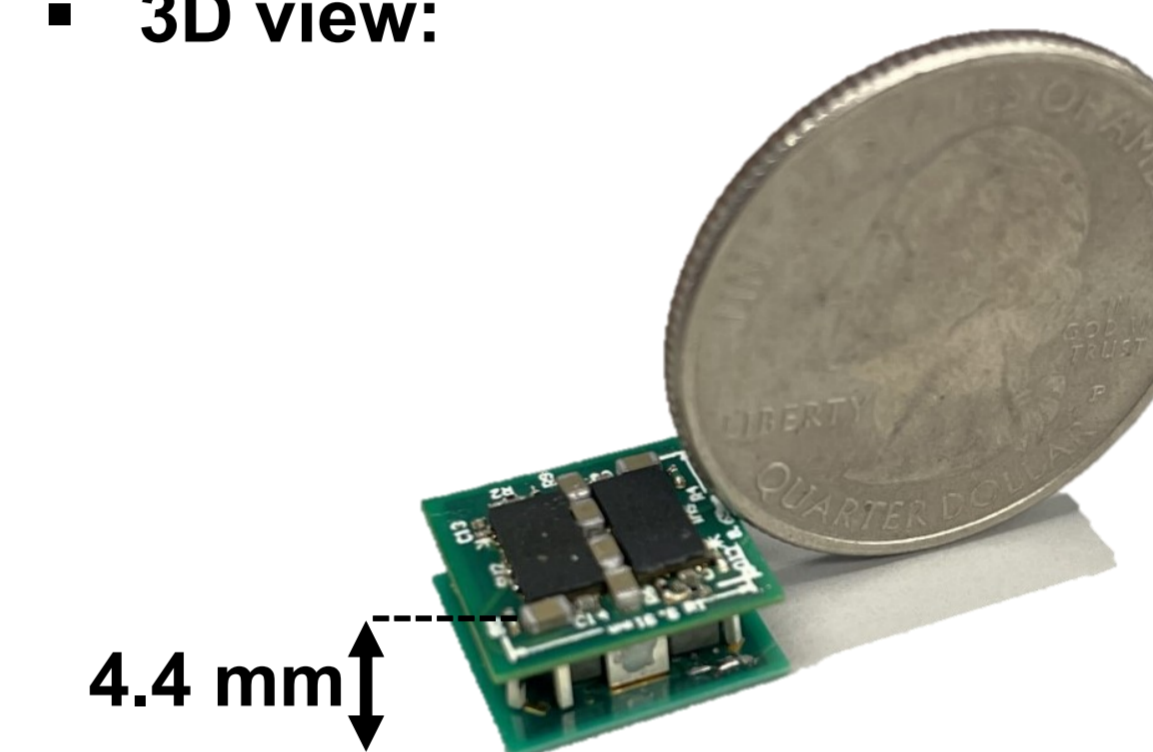
Top and bottom view:



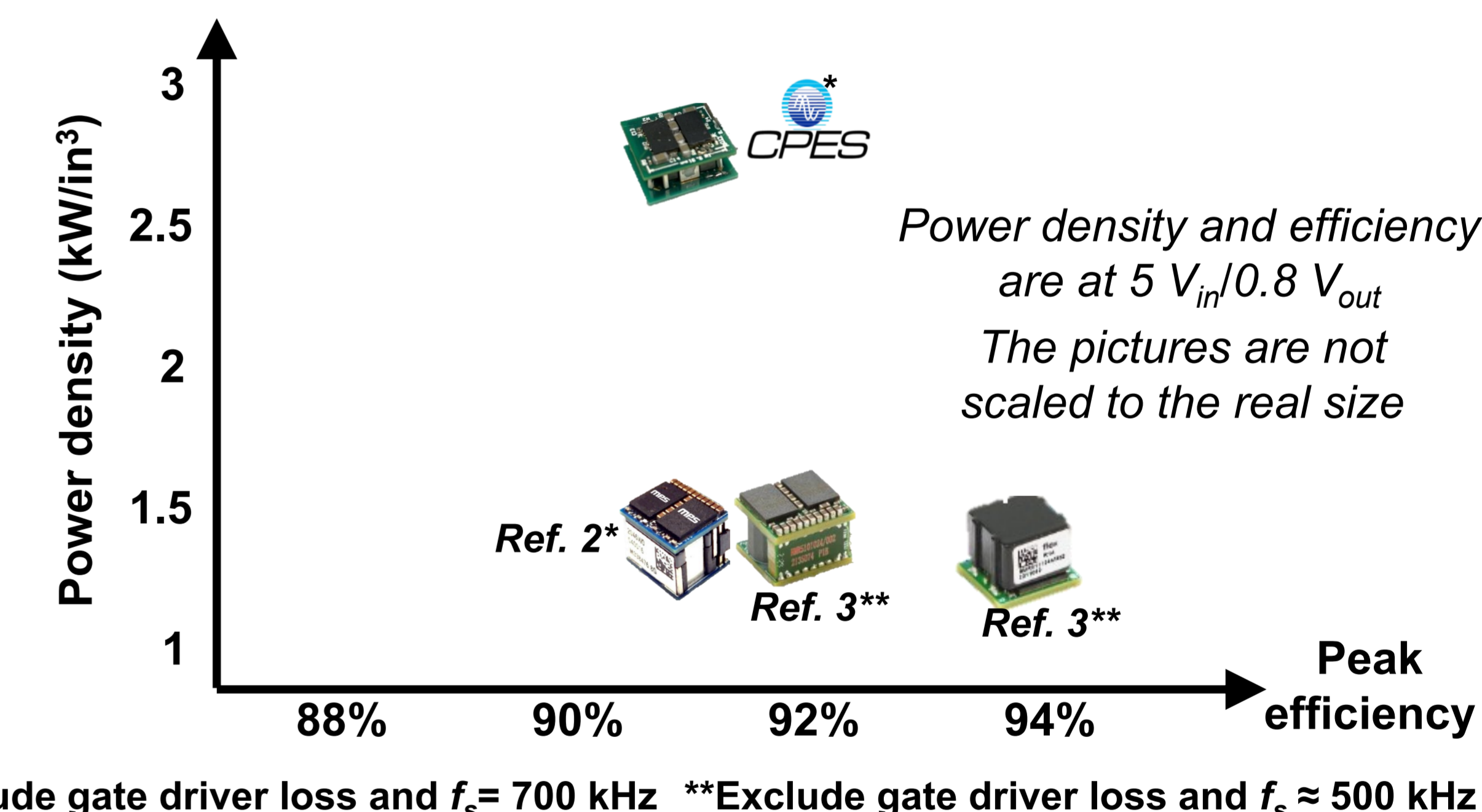
Specifications

| Variables | Values |
|--------------------|--|
| V_{in} | 4 V – 7 V |
| V_o | 0.8 V |
| I_{Load} | 80 A _{TDP} (130 A _{pk}) |
| f_s | 700 kHz – 1 MHz |
| Inductor footprint | 79 mm ² |
| Inductor height | 2.7 mm |
| L_{ss} | 55 nH |
| L_{tr} | 25 nH |
| DrMOS | MP86972 |
| C_{in} | 6 x 22 μF |
| Current density | 0.89 A _{TDP} /mm ² |
| Power density | 2.7 kW _{TDP} /in ³ |

3D view:



Power density and efficiency comparison:



*Include gate driver loss and $f_s = 700$ kHz **Exclude gate driver loss and $f_s \approx 500$ kHz

Conclusion:

- A negative coupled inductor structure with only two identical S-shape core shape is proposed.
- The inductor structure enables negative coupling with the shortest winding path.
- A 3D-stacked voltage regulator module with the proposed twisted core inductor achieving ~1.8x higher power density.

Key References:

- Dong Yan, "Investigation of Multiphase Coupled-Inductor Buck Converters in Point-of-Load Applications", PhD dissertation, 2009.
- <https://www.monolithicpower.com/en/products/power-management/data-center/mpc22163-130.html>.
- https://flexpowermodules.com/products?power_module_type=IPS.