

Research and Development of a Low-Inductance, High-Power-Density Power Module

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01. Industry Pain Points

High Stray Inductance & EMI

Excessive switching loss due to high inductance, causing severe electromagnetic interference and system instability.

Aluminum Wire Fatigue & Short Lifespan

Traditional Al wire bonds fail prematurely under thermal cycling, limiting module durability in harsh automotive environments.

Poor Heat Dissipation & Overheating

Inadequate thermal conductivity leads to junction temperature spikes, degrading performance and long-term reliability.

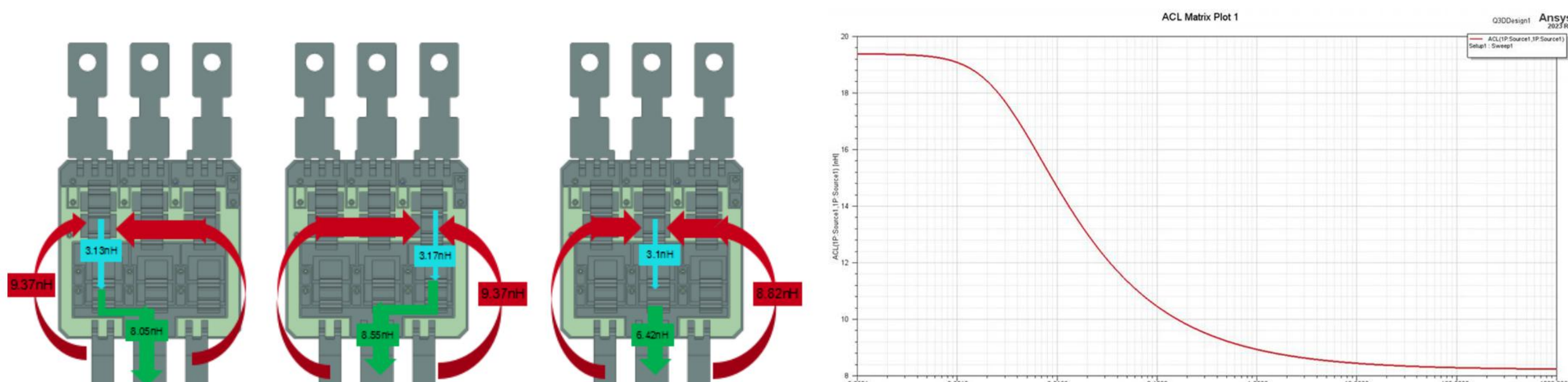
Bulky Size & Weight

Large form factor increases vehicle weight, reducing energy efficiency and compromising space utilization.

02. Core Advantages

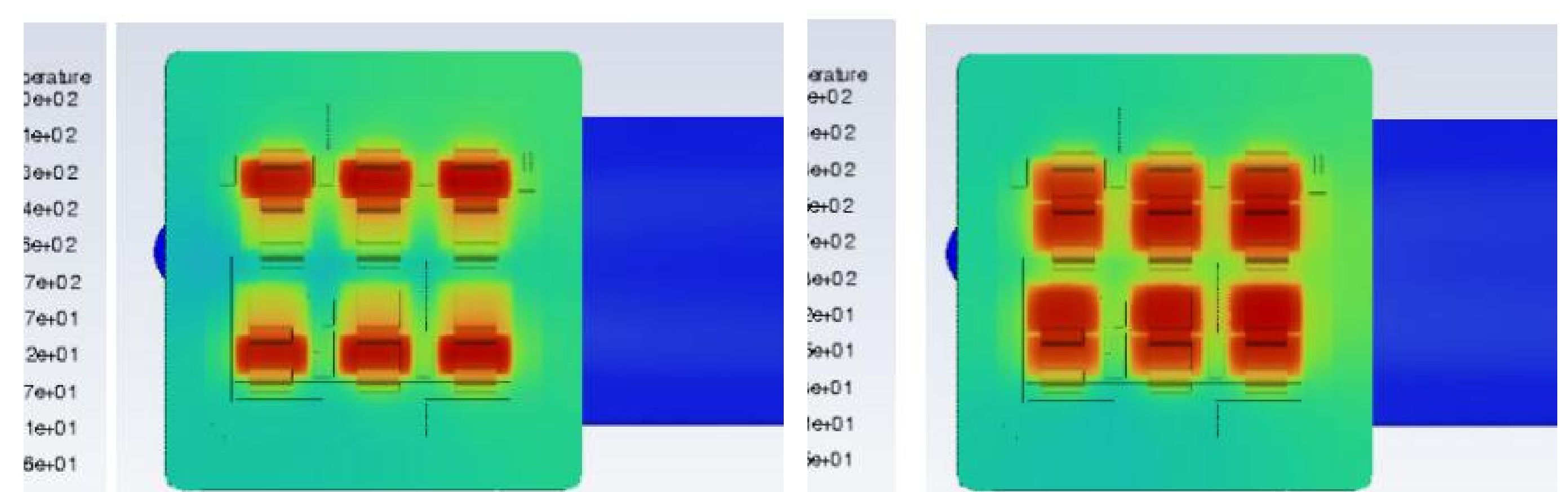
Ultra-Low Stray Inductance (Cu-Clip)

Advanced Cu-Clip interconnection with optimized terminal layout reduces parasitic inductance to $\approx 8\text{nH}$. This suppresses voltage overshoot, minimizes EMI, and drastically lowers switching losses for higher efficiency.



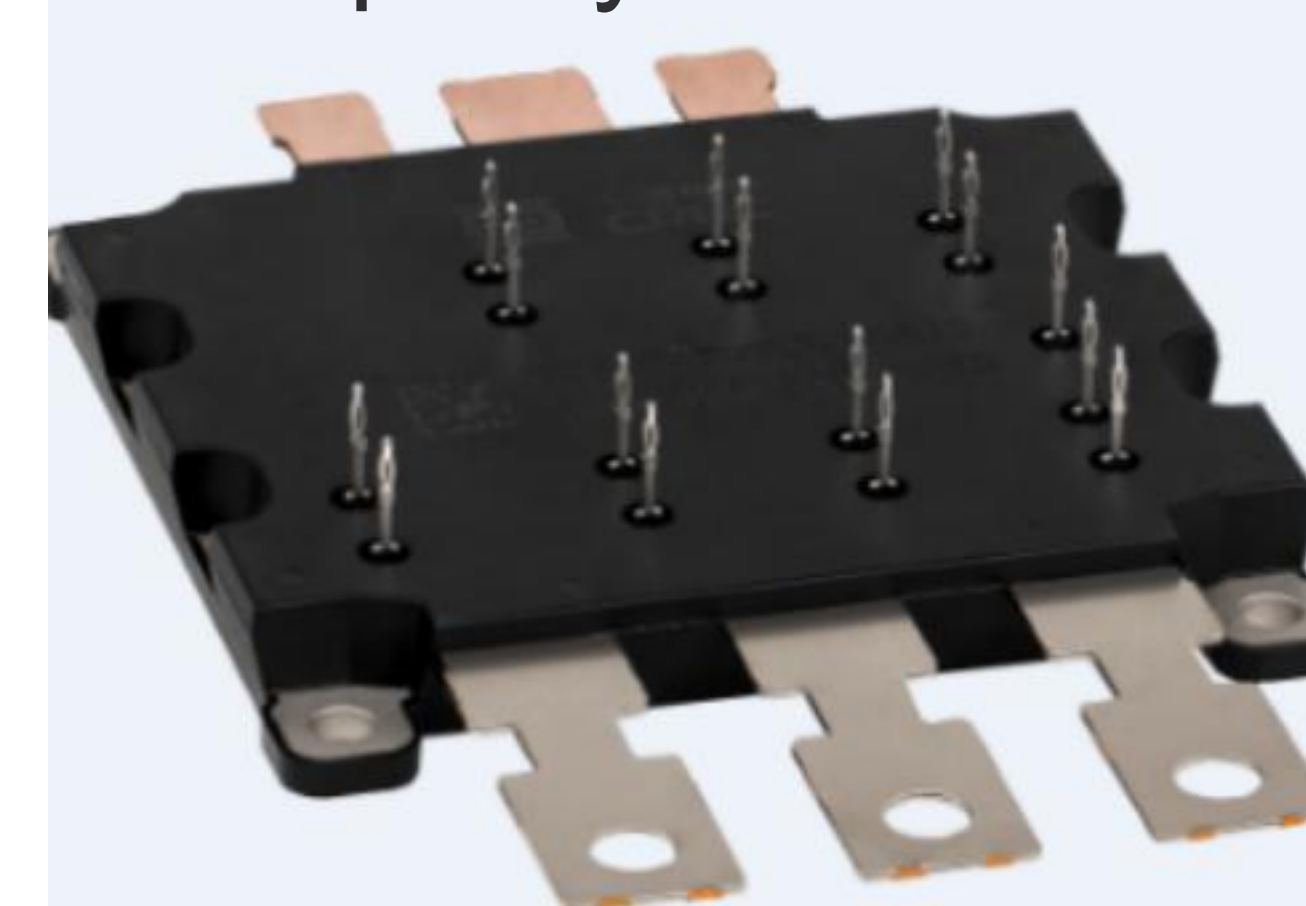
Extreme Thermal Performance & Density

High-thermal-conductivity molding compound achieves thermal resistance $< 0.238^\circ\text{C/W}$. At 350A peak current, junction temperature remains $\leq 155^\circ\text{C}$, enabling a compact, high-power-density design ideal for traction inverters.



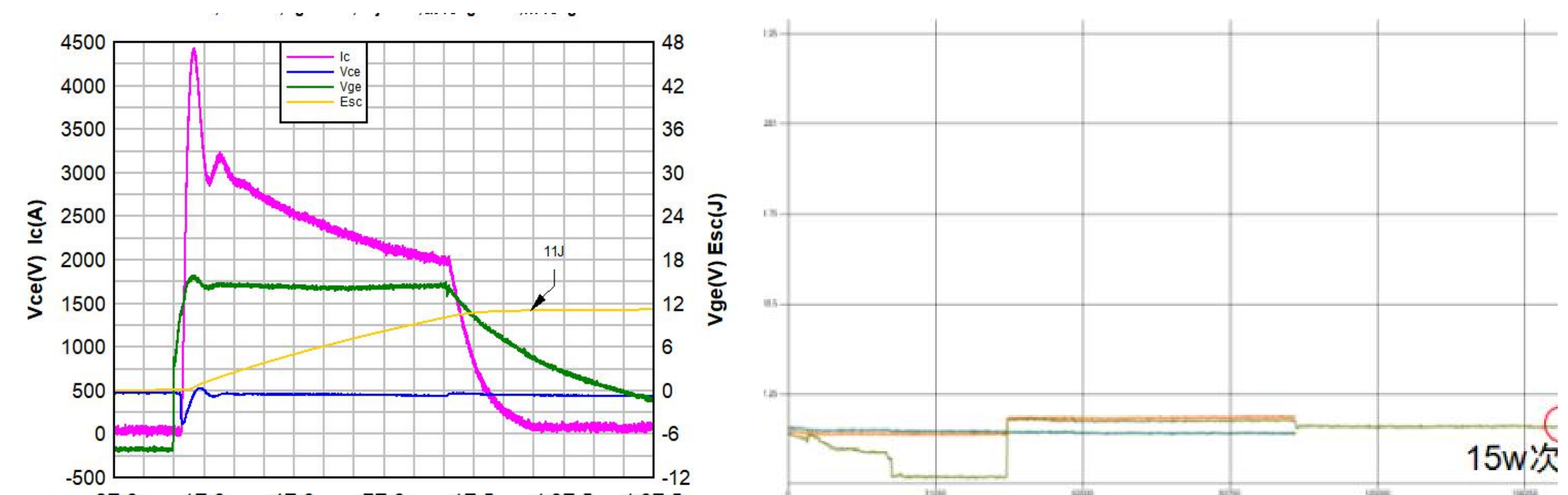
Integrated Transfer Molding and Sealing Process

Using a combo of frame and pin dual ultrasonic welding with transfer-molding packaging, it cuts the module size by 30% compared to traditional methods, saving a lot of cabin space; the standardized mass production process ensures super consistent quality and cost benefits.



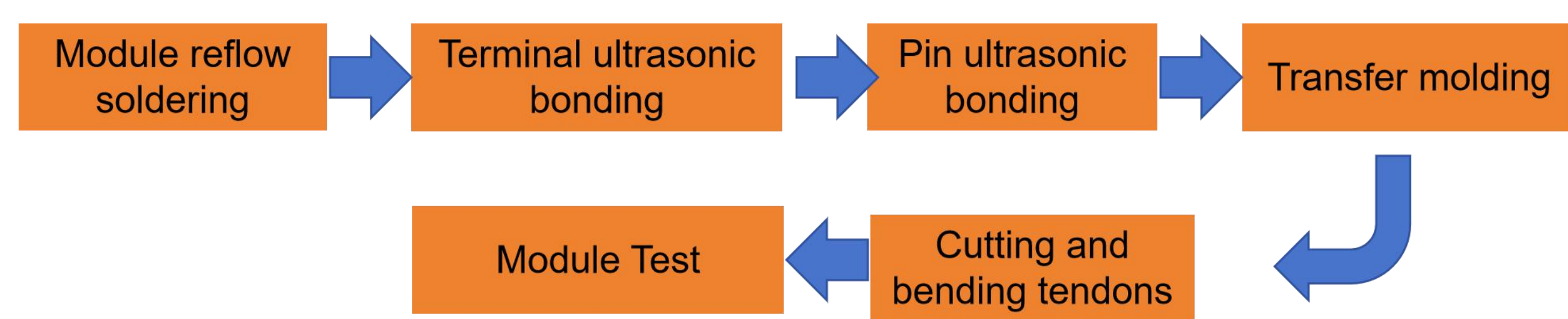
Automotive-grade ultra-high reliability

With a $9\mu\text{s}$ short-circuit pulse test at 20V (withstand energy 11J), the power cycle life exceeds 150,000 times; it has excellent vibration and temperature-humidity cycle resistance, perfectly suited for the harsh automotive conditions of -40°C to 125°C .



03. Fabrication & Prototype

The module uses frame ultrasonic welding, pin ultrasonic welding, and transfer molding sealing processes, which not only significantly reduce the module size but also improve its performance.



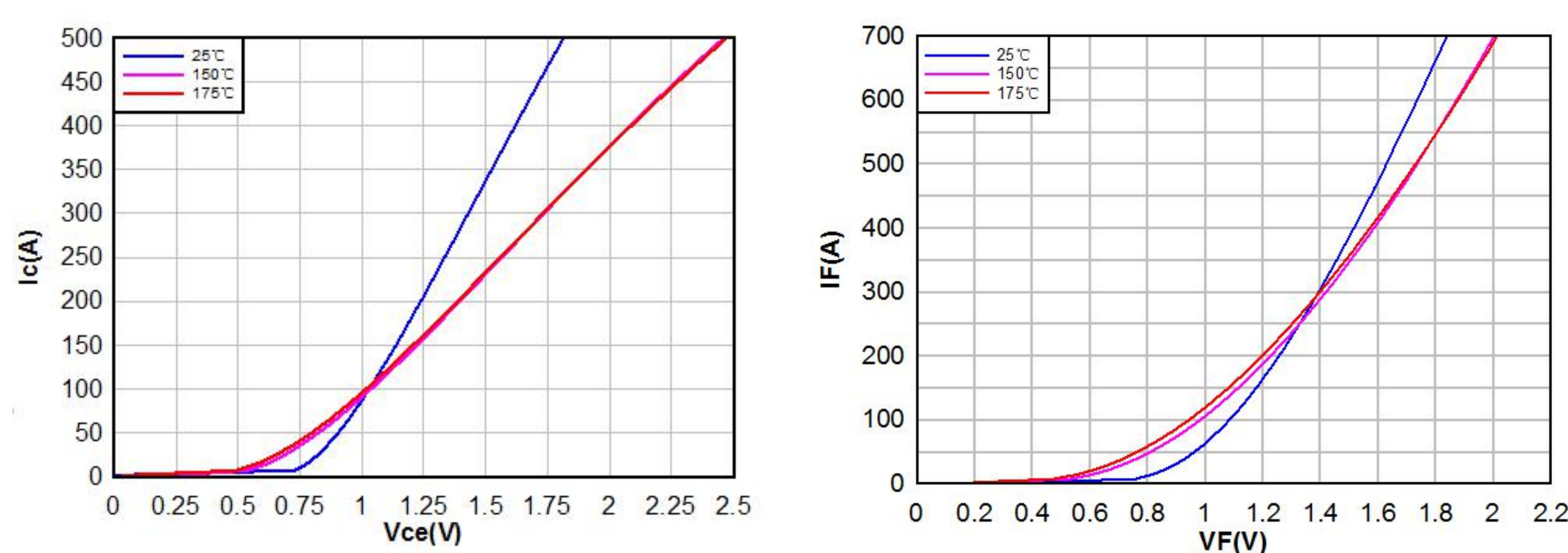
04. Performance Evaluation

Static Performance Evaluation

Static characteristics focus on IGBT saturation voltage drop V_{cesat} and freewheeling diode forward voltage V_f . Test data at multiple temperatures (25°C/150°C/175°C) are plotted as output characteristic curves.

- Key index at rated current 500A:

$$V_{cesat} \leq 1.6 \text{ V}; V_f \leq 2.25 \text{ V}$$



Short-Circuit Limit Capability Evaluation

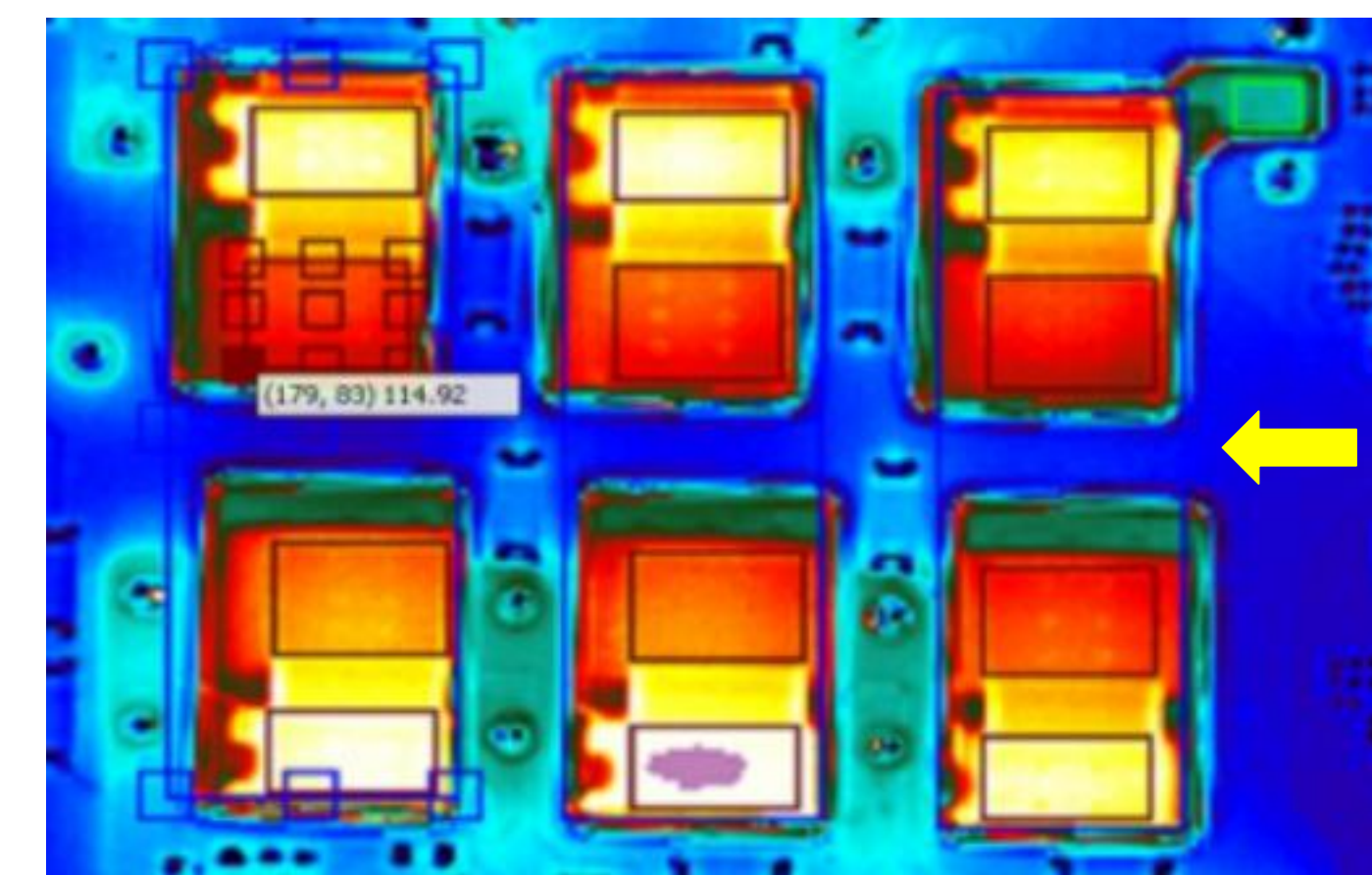
Test conditions: 25°C ambient, DC bus $V_{dc}=470\text{V}$, gate turn-on resistance $R_{gon}=2\Omega$, gate drive voltage $V_{ge}=20\text{V}$, short-circuit duration $T_{sc}=9\mu\text{s}$

- Short-circuit peak current: 4480A ($8.96 \times$ rated 500A current)
- Conclusion: Extra-wide short-circuit safe operation area, strong anti-shock reliability

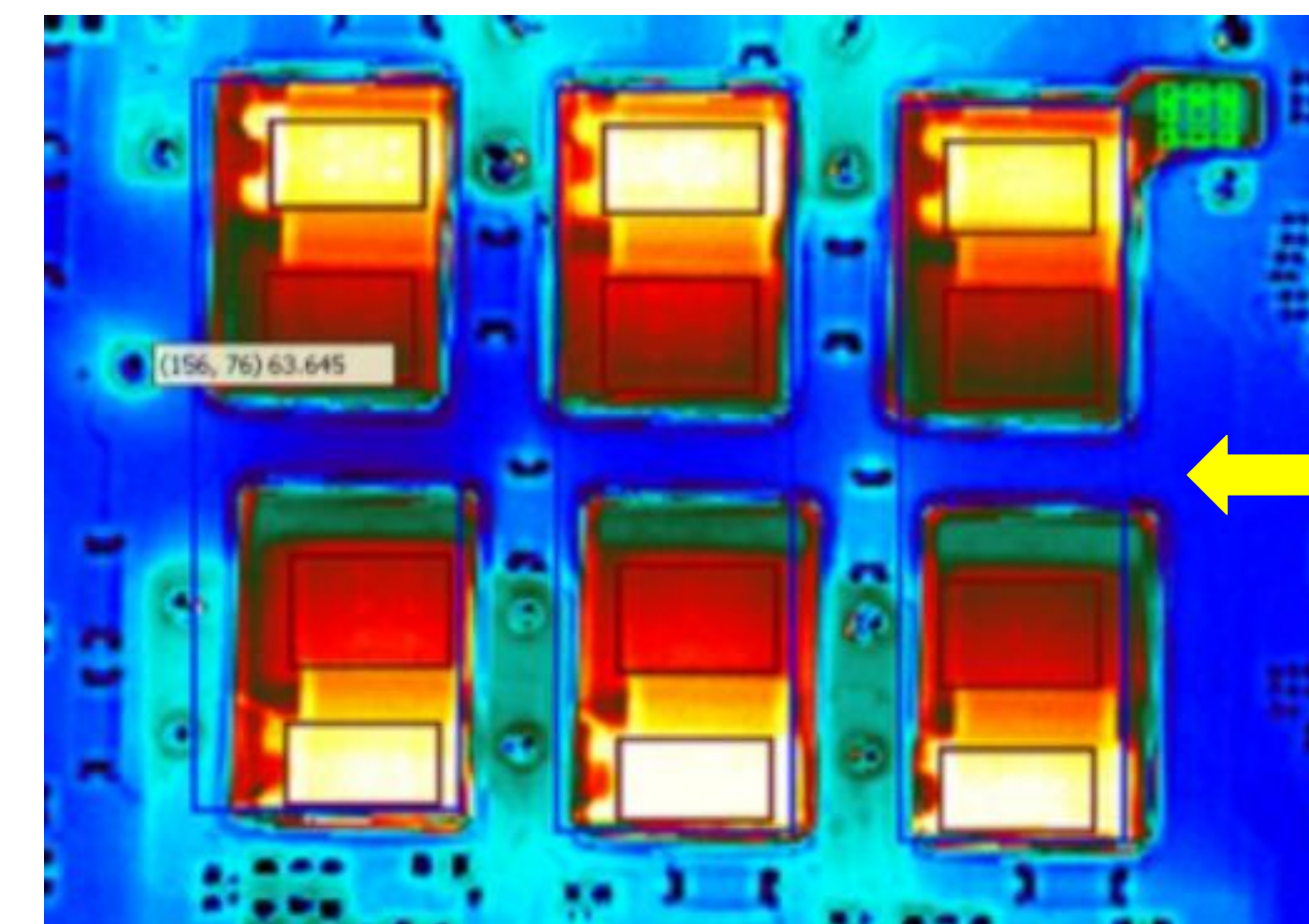
Application Performance Evaluation

Three core working conditions tested under 10kHz switching frequency, modulation ratio $M=0.4$, cooling water temperature 65°C, with infrared junction temperature capture and power cycling lifetime verification:

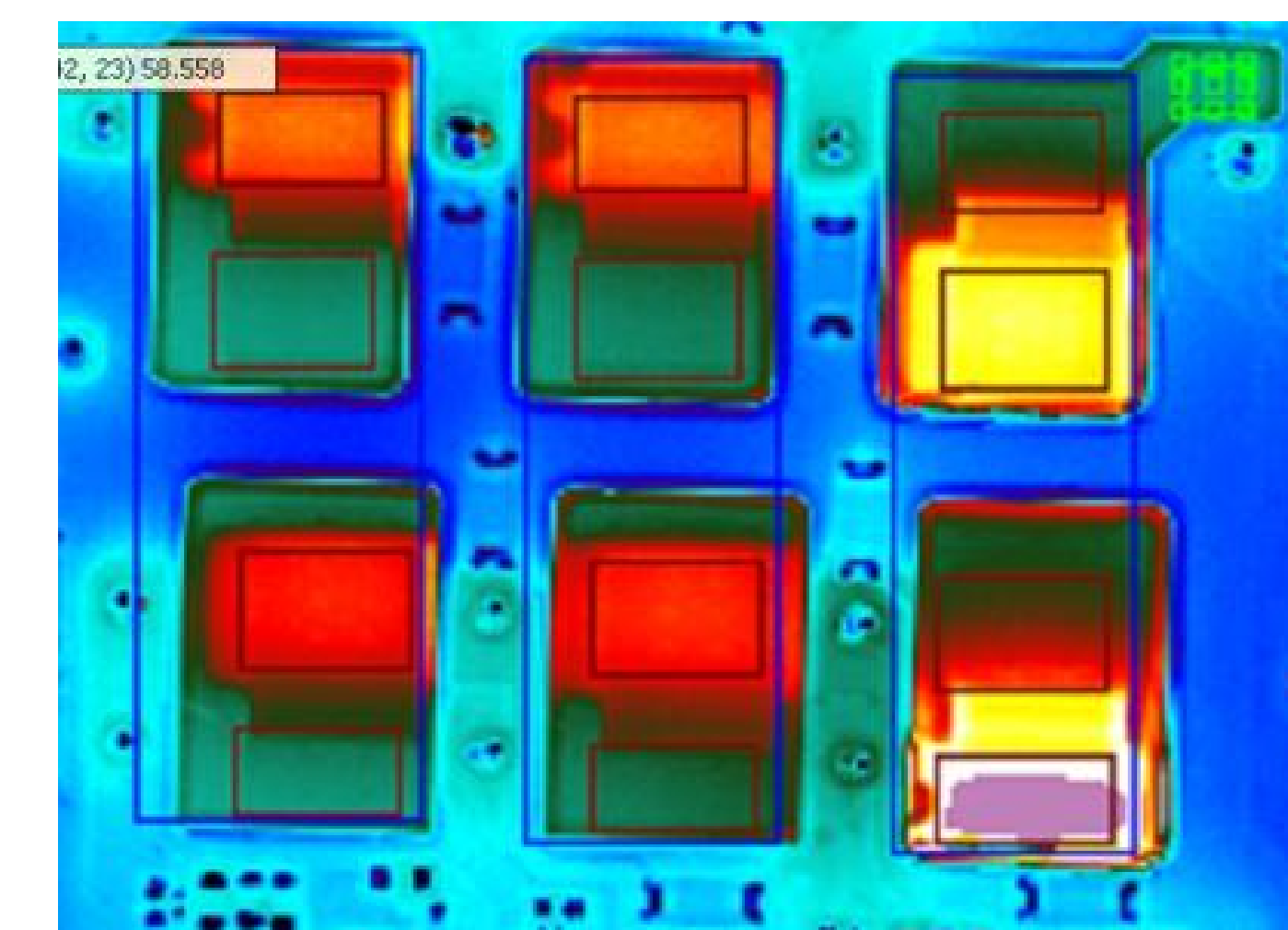
- Inverter Working Condition (350V/300Arms), max IGBT junction temperature = 118.2°C



- Rectifier Working Condition (350V/245Arms), max FRD junction temperature = 131.7°C



- Locked-Rotor Working Condition (470V/245A) max FRD junction temperature = 158.2°C



5. References

- F. Spinato, P.J. Tavner, G.J.W. Van Bussel, E. Koutoulakos, "Reliability of wind turbine subassemblies", IET Renewable Power Generation, 2009, 3, (4), pp.387—401.
- A. Golland and F. Wakeman, "Application of press-pack IGBTs in traction refurbishment", Twentieth Annual IEEE Applied Power Electronics Conference and Exposition, 2005. APEC 2005., Austin, TX, 2005, pp. 2030-2035 Vol. 3.
- Y. Yang, L. Dorn-Gomba, R. Rodriguez, C. Mak and A. Emadi, "Automotive Power Module Packaging: Current Status and Future Trends," in IEEE Access, vol. 8, pp. 160126-160144, 2020, doi: 10.1109/ACCESS.2020.3019775.

Summary: The application of the 800V/500A transfer - molded encapsulated IGBT device has significant advantages in weight reduction, and low losses. It highly conforms to the demands of the electric vehicle market, meets the requirements of high performance and high reliability for range - extended vehicles, and realizes low - cost, high - efficiency, and high - reliability voltage and power conversion.