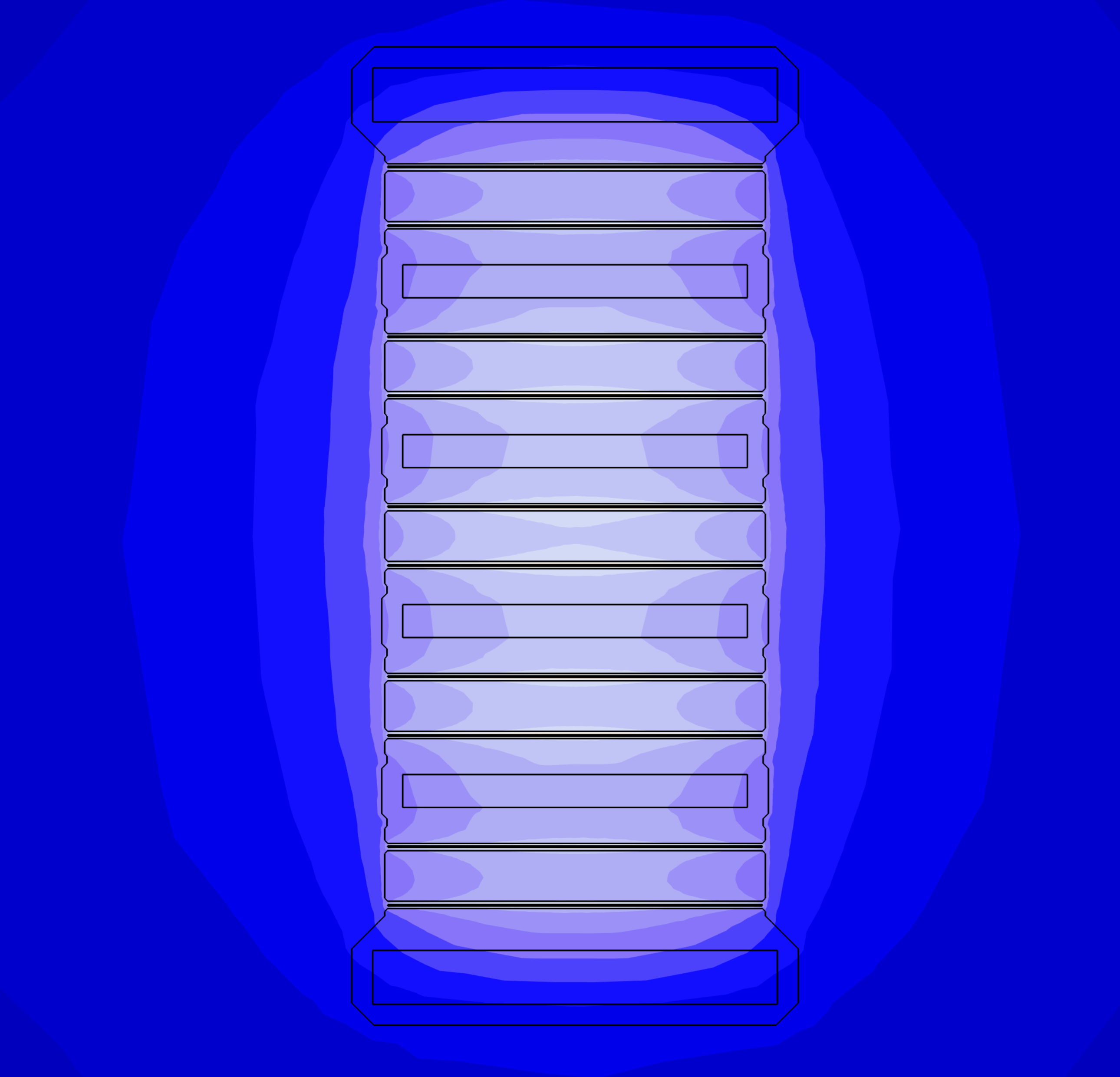




A Cooler Future: Thermal Modelling of Diamond Heat Spreaders

Diamond heat spreaders offer a promising route to improved thermal performance and power handling in high-power GaN RF devices.

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Abstract

Gallium nitride (GaN) power devices are leading contenders for high-frequency applications due to their robustness, high power density, and high electron mobility.^[1] However, commercial devices are increasingly limited by thermal constraints, resulting in **elevated channel temperatures**.^[2]

Diamond offers an attractive solution due to its exceptional thermal conductivity. This work developed a COMSOL Multiphysics® framework to investigate the conditions under which

diamond provides the greatest thermal benefit. For **large-periphery devices**, diamond enabled up to a **33% increase in allowable power dissipation** compared with CuW at a peak channel temperature limit of 220 °C.

The results provide guidance to Space Forge for the development of diamond heat spreaders and demonstrate how COMSOL Multiphysics® can address real-world thermal challenges.

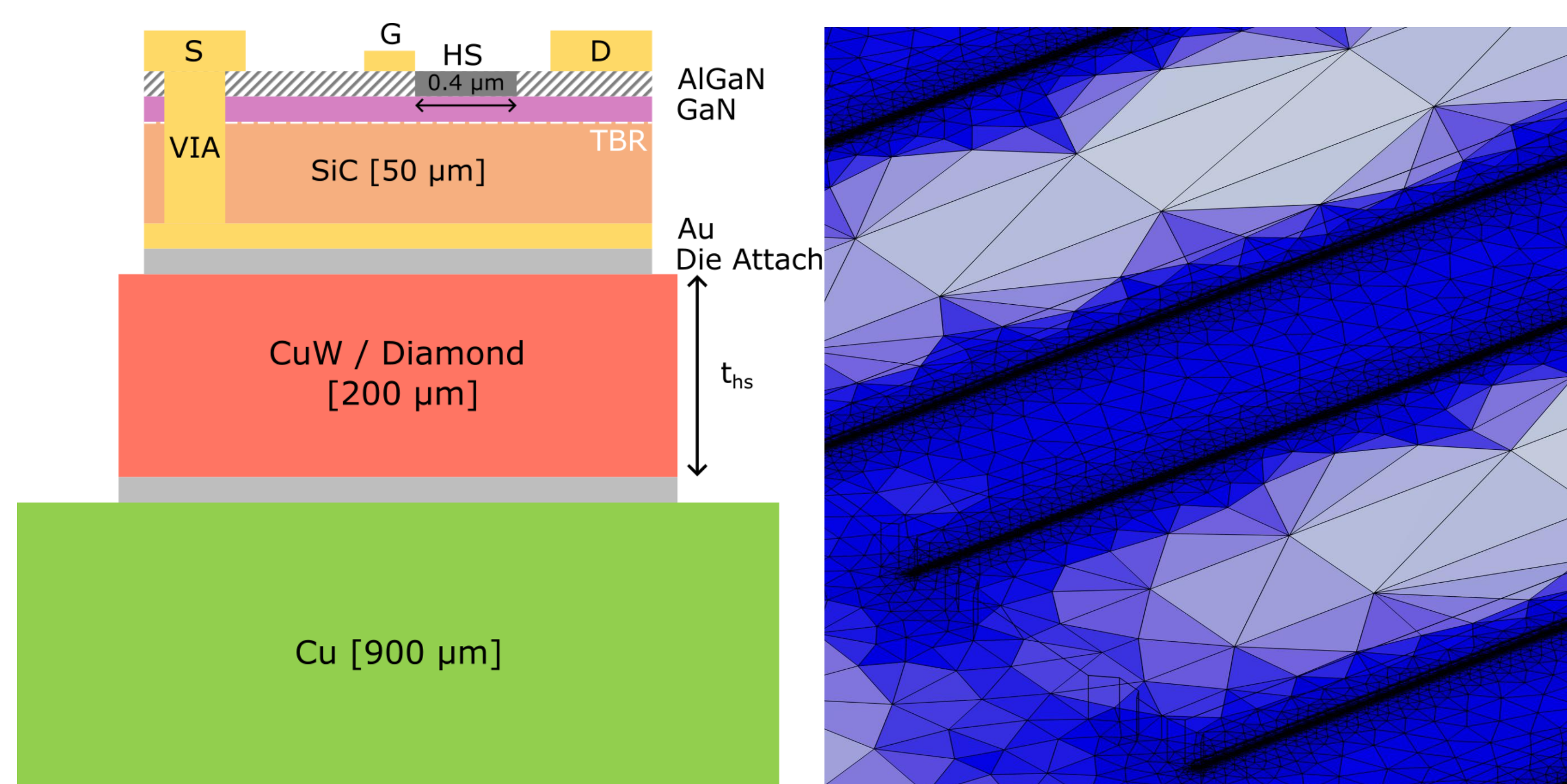


FIGURE 1. Device geometry (left) and refined mesh around the gate-channel heat source (right). Max. element size: 0.2 μm.

Methodology

Geometry: A 2D geometry was imported using discrete work planes and extruded into a 3D structure.

Mesh: Boundary, edge and swept meshes were used around the gate-channel region to resolve settle thermal gradients.

Power dissipation: Modelled as a volumetric heat source at drain-side edge.

Boundary condition: Heat sink maintained at constant temperature.

Parametric studies: Thermal boundary resistance (TBR), die attach, diamond thickness and diamond thermal conductivity were varied.

Results

- Diamond provided the greatest thermal benefit when series thermal resistances were minimised, with diminishing returns once heat flow became constrained near the source.
- Low TBR & a thin, high-quality die attach are therefore critical.**
- For a 10x125 μm cell, a 200 μm diamond heat spreader facilitated **33% higher allowable power dissipation than CuW** (Figure 2).
- At 25 °C, gains approached **50%** reaching **10 W/mm** under ideal interface conditions.
- In a full HPA, diamond still reduced peak channel temperature by **45 °C** at 17.5 W output-stage power dissipation.

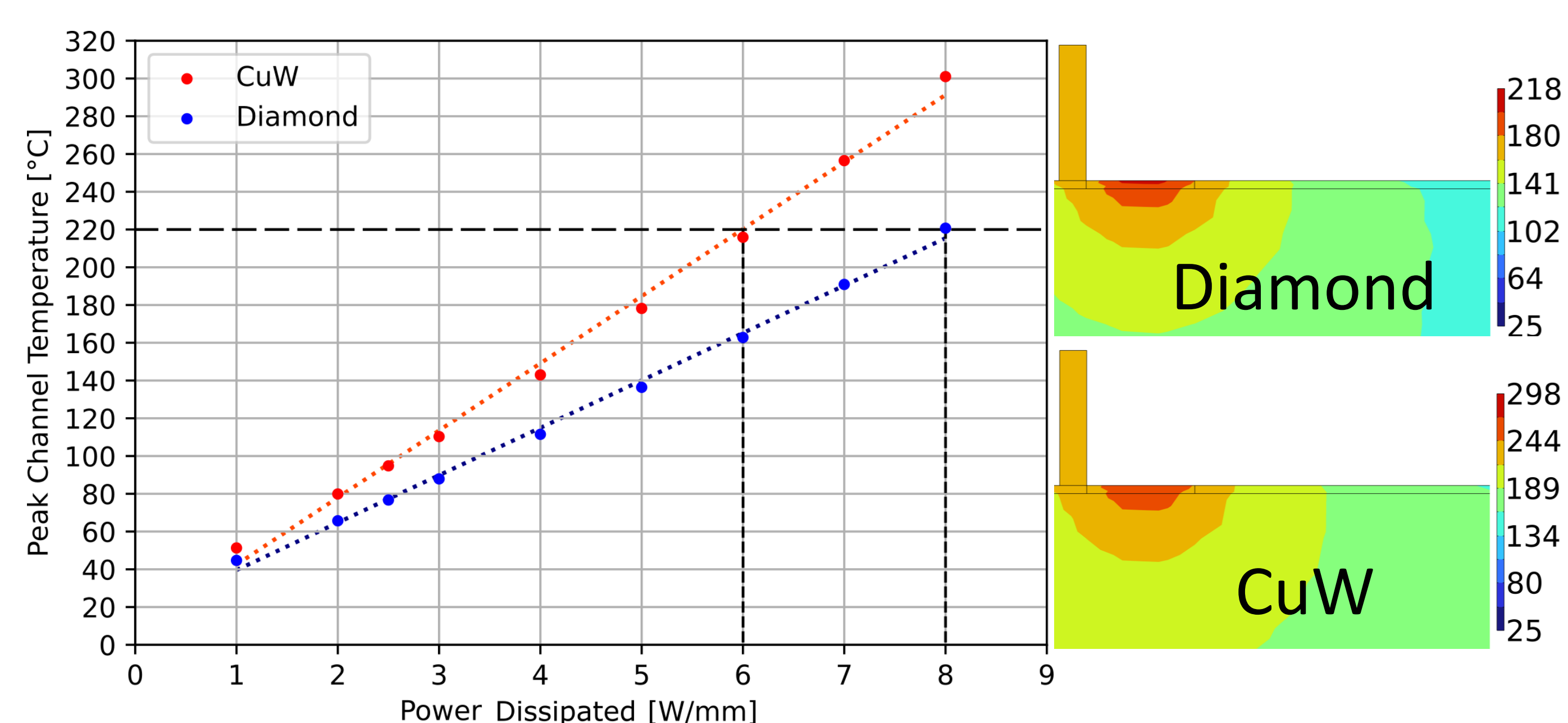


FIGURE 2. Peak channel temperature for a 10x125 μm cell (left) and simulated temperature distributions at 8 W/mm for diamond and CuW (right) with TBR, T = 25 °C & $k_{\text{diamond}} = 2000 \text{ W/mK}$.

REFERENCES

[1] Francis, D. & Kuball, M., "GaN-on-diamond materials and device technology: A review," in *Thermal Management of Gallium Nitride Electronics*, pp. 295–331 (2022).

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