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Design and simulation of conductive cooling for radio frequency superconducting cavities

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The RF accelerating module is crucial for imparting kinetic energy to particle beams in accelerators. Superconducting RF (SRF) technology offers key advantages over conventional room-temperature RF systems, including lower operational costs, reduced beam loss, and higher accelerating power. The superconducting cavity, SRF's core component, requires ultra-low temperatures. While liquid helium cooling meets this need, its complex and expensive infrastructure hinders SRF's widespread adoption. Recent advances in cavity manufacturing have improved quality factors (Q-values) and reduced heat loads to watt levels, enabling alternative cooling methods. This study investigates conduction cooling using compact cryocoolers for a 648 MHz superconducting cavity. Numerical simulations analyzed two cooling structures, focusing on configuration, material choice, and thermal contact resistance. Results show conduction cooling effectively maintains operational temperatures, with high-purity aluminum outperforming oxygen-free copper as a thermal bridge material. Maintaining thermal contact resistance below 10 $K \cdot cm^2/W$ is critical. These findings offer valuable guidance for designing more efficient SRF cooling systems.

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Footnotes

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