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Piezoelectric-Actuated Mechanical Contact Heat Switch for Cryogenic Applications

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This paper presents the development and experimental characterization of a novel piezoelectric cryogenic heat switch based on mechanical contact. The switch is designed for applications requiring dynamic and precise thermal control between 60 K and 120 K, where low parasitic heat loads, compactness, and long-term stability are crucial. Such requirements are increasingly relevant in quantum systems, cryogenic microscopy, and low-vibration scientific instrumentation, where efficient and reliable thermal management directly impacts performance and measurement stability.

Unlike conventional mechanical or gas-gap heat switches that require continuous actuation energy in the conducting state, the proposed design maintains thermal contact passively using a disc spring preload, consuming energy only during transition to the non-conducting state. The switch employs a multilayer flexure-based piezoelectric actuator to separate the thermal interface, enabling clear and reversible transitions between conducting and non-conducting configurations.

Performance was evaluated using a guarded heater method. The measured thermal conductance in the conducting state ranges from 8×10^3 to 1×10^4 W m^{-2} K^{-1} between 60 K and 120 K, corresponding to applied forces of 165–245 N. In the non-conducting state, the conductance falls below 55.4 ± 1.6 W m^{-2} K^{-1}, yielding switching ratios greater than 145. In addition to high thermal performance, the switch offers energy-efficient operation, simple electrical control, and compact integration, making it suitable for modular cryogenic platforms.

A comparative analysis with a previously developed gas-gap heat switch demonstrates enhanced conductance, energy efficiency, and implementation simplicity of the piezoelectric design. These results position the concept as a promising solution for advanced cryogenic thermal management in emerging quantum technologies, precision cryogenic microscopy, and space instrumentation.

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