Title:
Modular Quantum Thermal Devices: Integrating thermal functionalities

Abstract

Thermodynamics, the science of heat and work, has been one of the most successful physical theories developed by humankind, describing everything from car engines to the fate of the universe. Despite its down-to-earth approach, it has been expanded toward the uncharted realm of quantum mechanics, where physics behaves in mysterious and non-intuitive ways. This new endeavor seeks to deepen our understanding of the fundamental laws of nature and build novel machines capable of using quantum phenomena, giving rise to *quantum thermodynamics*. However, while researchers have advanced in understanding individual quantum thermal devices (QTD), combining multiple functionalities into a single, multipurpose system is still a challenge. More importantly, experimental progress has been limited to basic demonstrations. This project is inserted within this context and aims to design integrated QTDs capable of performing multiple tasks simultaneously, such as manipulating heat and storing energy. The research will focus on developing practical designs that can, in principle, be built and tested using cutting-edge technology, particularly superconducting platforms. To achieve this, the research is divided into three phases. First, we will develop different designs of QTDs. Next, we will use these designs to combine multiple functions into a single device, exploring the conditions needed to make it work and identifying any limitations. Finally, we will adapt them to work with real-world superconducting circuits, making them practical for experimental testing. By collaborating with leading experimental physicists, this project will help bridge the gap between theoretical studies and practical implementations, ensuring that the designs are feasible and useful. The results of this project have the potential to significantly impact the future of quantum technologies. Similar to the role played by Integrated Circuits (ICs) in modern electronics, these devices could reduce wasted energy, improve the efficiency of quantum computers, and pave the way for new applications in energy processing. By addressing this critical technological challenge, the project aims to push the boundaries of what is possible in quantum engineering, contributing to the development of sustainable and genuine quantum technologies for the future.