

# *Abstract*

The broader aim of this thesis is to enhance our understanding of heat current transport in mesoscopic and nanoscopic quantum systems. To accomplish this, we investigate how structural asymmetry influences steady state thermal transport in such small scaled systems. We divide our studies into two sub-classes. One subclass deals with construction of thermal devices for better manipulation of heat currents and the other deals with the investigation of anomalous transport phenomenon due to asymmetry. We employ spin and fermionic lattice models for studying these sub-classes and the analysis is done using the quantum Markovian master equations.

Specifically, for the first subclass we study the construction of thermal diodes which are the most fundamental small scaled devices needed to manipulate heat currents. In the initial part of this subclass, we study the heat current rectification effects in a two qubit (spin-1/2 particle) setup. These two qubits interact with each other via the Dzyaloshinskii-Moriya (DM) interaction and are coupled to two separate heat baths. Off-resonant magnetic field is applied on these spins and it is observed that this inhomogeneous magnetic field serves as the asymmetry required for inducing the heat rectification. For the later segment of this subclass, we study the potential of a heat diode to distinguish different topological phases of the Su-Schrieffer-Heeger (SSH) model. This study explores in detail the role of heat transport as a potential indicator of topological phase transition in the SSH model, and demonstrates how the efficiency of the diode can be exploited as the quantity used to distinguish between the different topological phases.

In the second subclass, we study an interesting transport phenomena called Current Magnification (CM) or Current Circulation (CC). The investigation of this phenomenon requires placing a multi-branched system between the two heat baths. CM occurs when in one of the system branches, the local heat current is larger than the total heat current, and in the other branch, the heat current flows in opposite direction of the thermal gradient. This is necessary for conserving the total current at the junction. Similar to our treatment of heat rectification, we initiate this subclass by studying a small quantum spin setup. Here, we establish that the geometrical asymmetry of having unequal number of spins in different system branches is enough to generate CM. Analysing this system in more detail, we realise that CM usually occurs near the point of intersection of two otherwise non-degenerate energy levels. We call this point the Additional Energy Degeneracy Point

(AEDP). Next, we examine CM in a quadratic fermionic network and provide analytical proof of its possible presence near AEDP. Subsequently, we apply this idea to different fermionic models with quadratic Hamiltonians and verify the relationship between CM and AEDP.

In our efforts while examining both these subclasses, it becomes apparent that while asymmetry is a crucial condition for observing heat current rectification and magnification, it alone is insufficient for either of these phenomena, and other complementary properties like anharmonicity or AEDP in the system are required.