Thermally Driven Spin Transport and Spin Seebeck Effect in a Magnonic Quantum Dot System

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Magnonics is a rapidly developing subfield of spintronics in which magnons—the quanta of spin waves—serve as carriers of spin current [1]. Owing to their bosonic nature, spin waves transport angular momentum and energy without the Joule heating intrinsic to spin currents generated by spin-polarized electron transport [2]. Furthermore, magnons can propagate over macroscopic distances, reaching several centimeters with minimal scattering, thereby significantly suppressing dissipative losses [3-5]. These favorable transport characteristics position magnonic systems as promising platforms for next-generation, energy-efficient information processing technologies and have inspired the proposal of numerous devices that exploit magnons as signal carriers. Understanding and controlling thermally driven spin transport in such systems is therefore of central importance for the advancement of magnon-based spintronic architectures.

In this work, I investigate the generation of spin bias induced by a temperature gradient applied across a system consisting of two magnetic insulators coupled via a magnonic quantum dot. Using the nonequilibrium Green's function approach, I derive expressions for the magnonic (spin) current and the corresponding heat current within the linear-response regime. I demonstrate that the applied thermal gradient gives rise to a magnetochemical potential difference between the magnon reservoirs, leading to the emergence of the spin Seebeck effect.

This study provides a microscopic theoretical framework and fundamental insight into thermally driven spin transport in hybrid magnonic nanostructures, and highlights temperature gradients as an effective control parameter for generating and manipulating pure spin currents, paving the way toward energy-efficient, low-dissipation magnonic spintronic devices.

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