Abstract

The study of low-temperature thermal transport provides unique insights into quantum materials, which enables us to test hypotheses and uncover novel phenomena. In our lab, experiments are conducted in the quantum regime facilitated by high-capacity Helium-3 inserts and superconducting magnets, allowing high-resolution measurements crucial for detecting reliable thermal signals. This thesis presents the relevant projects I have primarily worked on. After briefly introducing the standard analysis for thermal transport, I will discuss experimental protocols including measurement setup, calibration, and operation of Helium-3 inserts. I will then elaborate on two materials studied in detail for their thermal conductivity and thermal Hall effects.

The first material, $BaCo_2(AsO_4)_2$, exhibits competing interactions and intense phonon scattering. Its structure resembles Kitaev materials with frustrated spins in layered honeycomb planes, where a 0.5 Tesla field is sufficient to disrupt long-range ordering. We observed significant spin-phonon scattering, leading to the largest field-induced thermal conductivity enhancement among insulators. Intriguingly, the thermal conductivity scales exponentially in a non-perturbative way with a single parameter, temperature-to-field ratio. Whether this behavior is unique to $BaCo_2(AsO_4)_2$ or shared with other magnetically frustrated insulators is yet to be explored.

The second material is the parent compound of high-T_c cuprates, La_2CuO_4, which has been much less studied in low-temperature regime than other cuprates. Despite reports of large thermal Hall signals, our high-resolution measurements revealed no discernible Hall effect. The observed signal is at most 1/20th of reported values and lacks the expected temperature dependence, though the thermal conductivity measured aligns with the literature.

Electrical transport experiment can be easily integrated with other probes, and often complements thermal transport through offering additional insights. For $ZrTe_5$, I investigated a resistance anomaly under hydrostatic pressure up to 3 GPa, confirming its topologically trivial origin at atmosphere and observing a potential pressure-induced surface conduction channel. In WTe_2, its near electron-hole compensation renders quantum oscillations resolvable in thermal conductivity, which surprisingly differ from electrical results. These findings demonstrate electrical and thermal transport are not only individually valuable, but also collectively revealing in studies on quantum materials.