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Diffusive, Ballistic, and Quantum Thermal Transport in Thin Films and Nanostructures[1]

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The understanding and manipulation of heat flow in novel materials and small structures plays an essential role in current and future technologies, such as heat removal from integrated circuits and thermoelectric energy generation. This talk will discuss our recent work that shows there are still surprises in the fundamental physics of heat flow in such systems. One example is the role of phonons with long mean free path in heat conduction near room temperature. By adding scattering centers to the surfaces of suspended Si-N bridges via deposition of a series of (initially discontinuous) gold films, we have shown that phonons of surprisingly long mean free path and wavelength carry up to 40% of the heat even in this highly disordered material. This echoes recent results in crystalline materials, where other researchers are also finding large contributions to thermal conductivity from long mean free path via ultra-fast pump-probe measurements. A second example comes in a very different temperature range, where from 50 mK to 1 K, the thermal conductance in suspended Si-N structures very similar to the transition-edge sensors (TESs) used in state-of-the-art photon detectors shows unexpected contributions not well-explained by any model. The data, somewhat surprisingly, has a temperature dependence similar to that of a quantum-limited thermal conductance. Finally, we present evidence of a previously unknown mechanism for thermal transport in ferromagnets that is revealed by apparent violation of the Wiedemann-Franz law in very thin iron films.

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