

## Ultrafast Heat Transfer in Nanoscale Materials

David Cahill<sup>C, S</sup>

*Department of Materials Science and Engineering, University of Illinois, Urbana, IL, U.S.A.*

*d-cahill@illinois.edu*

On the macroscopic length scales of conventional engineering systems, heat transfer by conduction is generally a slow process well-described by the heat diffusion equation. The characteristic time-scale of diffusion scales with the square of length; therefore, at nanometer length scales, heat conduction can involve processes that occur on time-scales of picoseconds, i.e., a few trillionth of a second. We use ultrafast pump-probe optical techniques to directly study a variety of unconventional heat transfer mechanisms that are critical in nanoscale devices and nanoscale materials. Our studies encompass a diverse variety of systems (metallic nanoparticles for photothermal medical therapies, phase change materials for solid-state memory, and heat-assisted magnetic recording) and physical mechanisms (the thermal conductance of interfaces between dissimilar materials, the non-equilibrium between thermal excitations of electrons, phonons, and magnons, and the cross-terms in the transport of heat, charge, and spin). In this talk I will highlight three recent examples: i) ultrafast thermal transport in the surroundings of plasmonic nanostructures; ii) limitations on ultrafast heating of metallic multilayers imposed by electron-phonon coupling; and iii) the generation of currents of magnetization by the spin-dependent Seebeck effect and extreme heat fluxes exceeding  $100 \text{ GW m}^{-2}$ .