Nanoscale Heat Transfer and Phonon Hydrodynamics

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Abstract

Several experimental evidences show that macroscopic description of heat transfer phenomena in semiconductors through Fourier law is no longer accurate when the system length and time scales are comparable with the mean free path and relaxation time of the energy carriers (phonons). In such length scales (<1um) the interaction of phonons with the boundaries, ballistic effects and quantum effects become relevant and microscopic insight of the phonon dynamics is required.

The hydrodynamic heat flux equation, derived from Boltzmann equation by ensuring momentum and energy conservation laws, is a generalization of Fourier law that properly describes the interaction between phonons and the boundaries in a macroscopic framework, and predicts size effects and the reduced conductivities observed in experiments. This equation is similar to the Navier-Stokes equation for compressible fluids. Similar implementation in weak form has been done with stabilization. Also we implemented different boundary conditions such as Slip Boundary Condition and a periodic heat flux condition among others.

We developed COMSOL interface and we validated the results for different complex nanoscale geometries during my two months collaboration with COMSOL (I stayed a month in the COMSOL office in Sweden and a month in Grenoble). Future investigation will be conducted and more development of the model will be done in collaboration with COMSOL. The objective is to produce a validated interface to model heat transfer at the nanoscale.

Figures used in the abstract

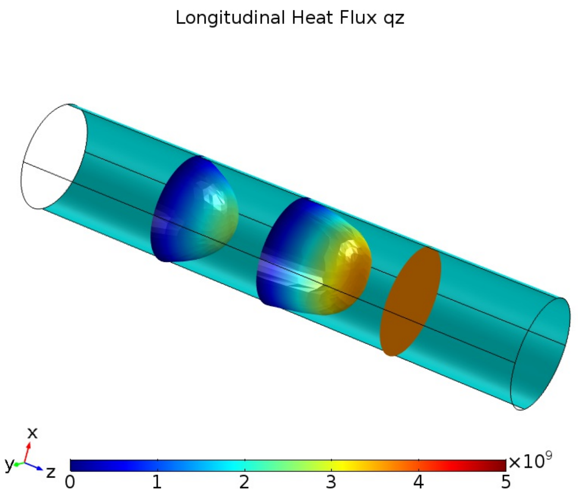

Figure 1: Poiseuille heat flux profile due to slip boundary condition and viscous effects.