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Higher-order, non-equilibrium, and nonlinear phonon transport in emerging materials: Predictions guiding experiments

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Date: Friday, 2nd August, 2019, 13:30-14:30
Venue: Room 232, 3F Faculty of Engineering Bldg. 2

Abstract:

Phonon thermal transport is crucial to many important energy applications. This talk will cover several unusual theoretical findings, including higher-order, non-equilibrium, and nonlinear phonon transport, and will show how these theories have inspired and guided experimental confirmations. The first part of the talk will establish four-phonon scattering as an important advance of the quantum theory of phonon scattering. For decades, four-phonon scattering had been persistently unclear and hence ignored. However, we have developed a rigorous perturbation method to predict four-phonon scattering rates, and established its significance on thermal conductive and radiative properties for nearly all materials at high temperature. Strikingly, it is significant even at room temperature for a range of materials such as boron arsenide, graphene, PbTe, and GaAs. The second part of the talk will discuss local non-equilibrium phonon transport in graphene and across interfaces. We show that electrons and different phonon modes in graphene are driven out of thermal equilibrium when irradiated with laser. Hence, the apparent thermal conductivity obtained from Raman spectroscopy needs careful interpretation. We also show that phonons are out of local thermal equilibrium across interfaces. We have developed non-equilibrium Landauer approach and multi-temperature models to account for such effects. The third part of the talk will cover nonlinear thermal transport in graphene. We have predicted that asymmetric graphene nanoribbons function as thermal diodes, which has been experimentally confirmed recently.

Biography:

Dr. Xiulin Ruan is a professor in the School of Mechanical Engineering and Birck Nanotechnology Center at Purdue University. He received his B.S. and M.S. from the Department of Engineering Mechanics at Tsinghua University, in 2000 and 2002 respectively. He then received an M.S. in electrical engineering in 2006 and Ph.D. in mechanical engineering in 2007 from the University of Michigan at Ann Arbor, before joining Purdue. His research and teaching interests are in multiscale multiphysics simulations and experiments of phonon, photon, and electron transport and interactions, and he has published over a hundred journal articles on these topics. He received the NSF CAREER Award (2012), Air Force Summer Faculty Fellowship (2010, 2011, and 2013), ASME Heat Transfer Division Best Paper Award (2015), Purdue University Faculty Scholar Award (2017), and other awards. He currently serves as an associate editor for *ASME Journal of Heat Transfer.*

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