ME Seminar

MECHANICAL ENGINEERING
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Energy Conversion at the Micro- and Nanoscale: Opportunities in Energy Generation and Healthcare

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ABSTRACT

Technologies that enabled miniaturization of transistors have sparked scientific exploration of nanoscale phenomena in various disciplines, including heat transfer. Probing energy transport at the nanoscale has profound implications on our solutions to the global challenges of climate change and human health. In this talk, I will describe high-resolution calorimetric techniques that facilitated exploration of heat/energy transport at the nanoscale. First, I will introduce how the radiative heat transfer (RHT) between two objects separated in vacuum changes as the gap size between them is reduced from tens of micrometers to tens of nanometers. At larger gap sizes, the RHT is well described by Planck's law and is bounded by the blackbody limit. As the gap size is reduced, electromagnetic surface modes start tunneling across the vacuum gap and contribute to orders of magnitude enhancement in energy transfer over that of the blackbody limit. I will present how state-of-the-art experiments allowed understanding of the fundamental limits to this near-field RHT and introduce the notion of a near-field Wien's law. Next, I will describe how near-field effects can be employed to achieve novel heat to electricity conversion technologies; near-field thermophotovoltaics, in specific. Through precise experimental techniques and detailed theoretical modeling, we have demonstrated—for the first time—up to ten-fold enhancement in electrical power output from an InGaAs photovoltaic cell placed tens of nanometers away from a hot Si emitter at 1000^0C. These systems can recover otherwise wasted heat in industrial systems, and unlike conventional heat engines, are noiseless, occupy less space, and are easy to operate. Finally, I will discuss the development of a sub-nanowatt resolution heat calorimeter for metabolic heat output measurements on individual C. elegans worms, a biological model organism. Such studies are expected, in the long term, to enable insights into cellular mechanisms involved in ageing and diseases like cancer. The presentation will close with a discussion on the broader implications of these phenomena and opportunities for real devices.

ABOUT THE SPEAKER

Rohith Mittapally is a postdoctoral research fellow in the Department of Mechanical Engineering at the University of Michigan, where he also obtained his Ph.D. in 2021. His primary research focus is the development of precision techniques for probing radiative thermal phenomena at the nanoscale. He is also interested in developing high-throughput calorimetric techniques for metabolic measurements on individual biological cells. Prior to his time as a graduate student, he worked as an Electrical Engineer at Eaton India Engineering center, Pune from 2014-2015, where he developed commercial lighting products for hazardous locations. He studied Mechanical Engineering (B.Tech) at Indian Institute of Technology Madras (2009-2014) with a specialization in Energy Technology (M.Tech).

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