PhD Position

YEAR 2019

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Ballistic-diffusive heat transfer in low-dimensional semiconductor systems

Supervisors :
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SCIENTIFIC CONTEXT :

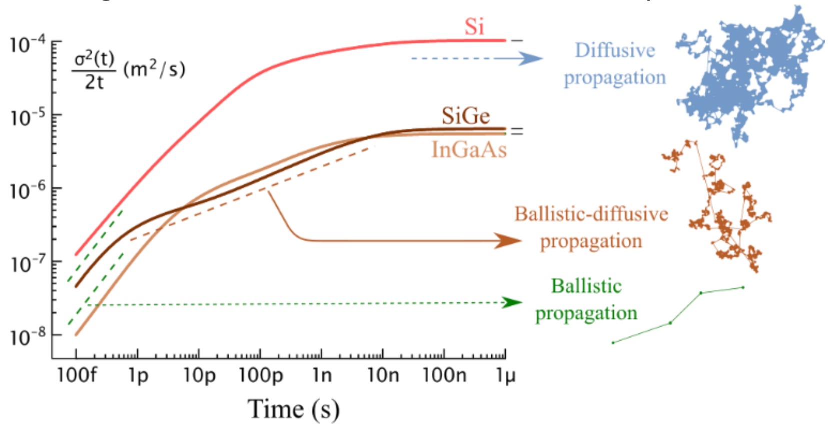
This work aims to push further the knowledge on heat transfer mechanisms at short space and time scales in nanostructured semiconductor materials. The goal is to study the propagation of heat carriers called phonons in ultrafast heating when classical heat diffusion theory is not valid anymore. To do so, two different theoretical but complementary approaches will be considered. First, a superdiffusive modeling based on the mathematical framework of Lévy flights will be carried and, in a second time, compared to a numerical approach based on Monte Carlo simulations.

Using those methods, we will be able to provide a better understanding of ballistic-diffusive heat transfer in nanostructured materials but also to support the experimental work of our collaborators. Ultimately, the main objective of this PhD proposal will be to fully master those new ultrafast processes of heat transfer, tailor them and design the first artificial Lévy material.

PROJECT DESCRIPTION :

In the context of a general size reduction of the microelectronic devices and components associated to new ways of material deposition, significant progresses have been reached in various domains of the scientific research. Nevertheless, THE limiting factor to new outstanding breakthroughs concerns heat management and local thermal hotspots.

At sub-micrometric scales, numerous theoretical and experimental results have showed that the underlying phenomena could not be explained neither understood by the classical physical laws and a new modeling must be developed. For example concerning ultrafast heat transfer, an intermediate regime between the well-known ballistic and diffusive transport has been demonstrated. This regime is now called ballistic-diffusive and may last tens of nanosecond in the typical timescale of the micro-electronic device working range.



In the frame of a French ANR research project based the detection and the study of this new regime, we wish to establish a new thermal metrology for nanoscale devices. To do so, our approach will be based on theoretical and numerical considerations. First, The resolution of Boltzmann's transport equation for phonons will be carried out using Monte Carlo simulations. This approach will simulate heat transport in nanostructured Ge materials with containing a wide distribution of nanoparticles. A complementary approach based on Lévy Flights dynamics will be also developed. This statistical framework gives new insight to heat transfer and introduce the concept of superdiffusivity. Those two parallel methods will produce a necessary knowledge to predict and tailor heat transfer behavior of nanostructured materials deposited by our partner in the frame of this project and support the experimental results obtained in the lab.

Ultimately, this PhD work will provide a new metrology for nanoscale heat transfer in order to tailor, control and amplify ballistic-diffusive regime to build the first artificial Lévy material for phonons.

SKILLS :
The candidate will join an active team in nanoscience research at LEMTA. His work will be supported by a solid network of national and international collaborations. During his academic study, the candidate must have developed skills and knowledge in heat transfer, solid-state physics. Theoretical and numerical skills, acquired during internships in solid-state physics and nanoscale heat transfer would be particularly appreciated.

DURATION : 3 YEARS

WAGE : ~33K€/YR