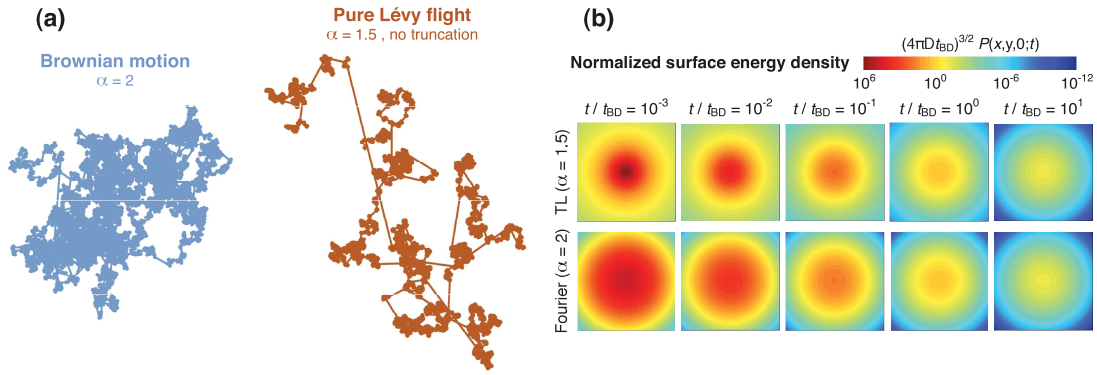
THESIS TITLE : Nanoscale Heat Transfer in Non Fourier Materials Studied with Picosecond Time resolved Thermoreflectance

RESEARCH PROJECT : The main goals of the thesis are to explore and develop a new instrumentation to probe ultra-fast (100 femtosecond) energy transfer in nano structured semiconductors. This ultrafast energy transfer is known as ballistic-diffusive regime, and can be described by the frame of Lévy Walks theory (i.e. super-diffusive regime see figure below). Over the past decade, rapid improvement of experimental techniques devoted to "nano" materials characterisation has arisen. For instance, Time-Domain Thermoreflectance (TDTR) and Scanning Thermal Microscopy (SThM) are now well-established techniques to probe energy transport in nano-structured materials. Yet, if those approaches respectively allow spectacular temporal or spatial resolution of heat transfer at nano-scales, they can scarcely describe the ballistic-diffusive regime that exists when length scale and energy carriers mean free path are similar. The latter behaviour is theoretically expected in different semiconductors. It represents a longstanding problem in nanoscale thermal transport for several engineering applications such as heat management, thermal hot spots, thermal boundary resistances, etc. In this framework, the thesis intent to design a new instrumentation to probe super-diffusive phonon transport in nano-materials called Spectral Phonon Super-diffusion Sensor (SPSS). This challenging task shall tackle several scientific issues, especially in the development and the calibration of the SPSS. Among them, there is the handling of a TDTR heterodyne device to work at frequencies up to 10 THz, where thermal wave propagation dominates, keeping low signal to noise ratio. Another critical point is to study artificial Lévy materials mixing alloy and nano- inclusions which will be responsible of super-diffusive behaviour with respect of the modelling pathways. Modelling issues are also possible bottlenecks to the achievement of the project as nanoscale heat transport simulation often imply to use large computational resources and lies on physics which is not fully understood for some crystalline materials and alloys. The latter points are considered in the present project and alternative paths are considered to overcome such issues.
In addition to the development of a new characterisation device and models for nanoscale material thermal properties characterisation, the thesis will aim to deeply investigate innovative nano-materials that will be useful for several technologies like electronics, energy, sensors, etc. Examples of that could be improved cooling of electronic devices, thermoelectric materials with high figure of merit, development of ultrafast magnetic switching materials, etc.



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