PhD Project: « Applying Stocastic Thermodynamics to micro and nano systems »

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Project description:

Stochastic thermodynamics is becoming an important tool to analyze the behavior of micro and nano systems such as for example molecular motors and nano-devices. In these small systems the role of thermal fluctuations cannot be neglected and the work, the heat and the entropy fluctuate too and cannot be characterized only by their mean values but their probability distributions are important too. This is clearly very important when one tries to define the efficiency of a device, the energy transfers between two thermal sources and the connection between thermodynamics and information. (See Lutz-Ciliberto in Physics Today September 2015 for a general introduction). The last problem is related to the famous problem of Maxwell demon.

In our laboratory we analyze these questions both experimentally and theoretically. Our tools are optical tweezers which allow us to trap and to displace Brownian particles and to let them to interact. The model are often based on coupled Langevin equations. The other experimental tool that we use are electric circuits and AFM. These systems are very versatile and allow us to construct experimental models with which we can address simple and fundamental questions on the above mentioned open problems.
During the previous thesis (see for example Antoine Bérut thesis) we have studied the energy transfer between colloidal particles kept at different temperatures. The other important measure that has been performed is the measure of the minimum energy necessary to produce a bit of information. In collaboration with theoreticians in Orsay we recently started a new activity in Short-Cut to Adiabaticity (STA) which is a general method to reach equilibrium faster than the relaxation time.

In the future we plan to further develop (STA), to study the efficiency of small systems, the role of effective temperature (i.e. temperature artificially introduced) and to construct simple Maxwell demon in order to strength the relationship between information and thermodynamics. Another development will be the interaction of Brownian particles coupled by complex potential such as for example those developed by confined phase transition and by coupling the particles with single DNA brains.

All of these problems are excellent subjects for a PhD thesis and the M2 internship. The candidate could make a choice among them.

The student will learn complex and updated techniques in optics, electronics, data analysis, micro-manipulation, AFM and MEB. From a theoretical point of view he/she will learn how to compare experimental results with stochastic models in out of equilibrium thermodynamics and complex systems.