Measurements of thermal noise in a solid in non-equilibrium steady states

Giacomo Ciani – INFN and University of Padova

Livia Conti – INFN Padova

Alvise Pizzella – INFN and University of Padova

Thermal noise (TN) is one of the fundamental noise sources affecting the performance of modern gravitational waves (GW) interferometers. In thermodynamic equilibrium conditions, TN is described in great generality by the fluctuation-dissipation theorem (FDT) and well understood. However, the behaviour of thermal noise in systems out of thermodynamic equilibrium is little explored, from both an experimental and theoretical point of view. We investigated experimentally TN dependence on heat fluxes in non-equilibrium thermodynamic steady states (NESS); these conditions are currently present in GW interferometers due to, for example, absorbed laser power in the main optics.

We study the spontaneous vibration fluctuations of a mechanical oscillator consisting in the first longitudinal mode of a macroscopic aluminium rod with one end fixed and the other loaded by a cuboid mass . We heat the cuboid mass in order to induce a heat flux through the rod and measure the temperatures of the two rod ends , while maintaining the piece around room temperature. We measure the spontaneous motion of the cuboid mass, and look for dependences on the average temperature T and temperature difference ΔT. These measurements extend results already published on thermal noise in solids in NESS [1]. In our experiment we employ a quadrature interferometric readout which allows us to explore states with higher temperature difference. Our results support the idea that in presence of steady states with heat fluxes, the thermal noise becomes dependent not only on the absolute temperature but also on the heat flux or temperature differences.

We discuss the importance of these results in the context of third generation GW interferometric detectors.

[1] L. Conti et al., J. Stat. Mech.: Theory and Experiment, 2013(12):P12003, 2013