Low temperature nanomechanical probes: from linear to nonlinear regimes

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Low temperature physics has always been concerned with mechanical devices used as tools for condensed matter experiments: from vibrating wires, oscillating spheres to torsional oscillators and quartz tuning forks probing Quantum Fluids. Solid-state matter is under intensive investigation using mechanical devices as well, and for instance quartz tuning forks are also widely used for low temperature STM or μSQUID experiments.
We have developed and studied at low temperatures micro and nanomechanical cantilever-based oscillators, using standard fabrication processes and lock-in detection techniques. Sizes range from mm long and 10 μm thick structures (kHz resonance), to 10 μm long and 150 nm thick (MHz resonance). The devices can be used immersed in a fluid, or as probes for solid matter deposited as a coating. We demonstrate that these structures operate in an extremely broad dynamic range, from a linear to a very nonlinear regime. The nanomechanical oscillators make use of parametric amplification, enabling gains up to a factor of 100, for oscillations ranging from Angströms to fifty nanometers. We demonstrate that a 0.5 % resolution on the measurement of friction processes can be achieved. Analytic mathematical tools are available to describe their dynamics, in the full dynamic range.