physikalisches Kolloquium

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A coherent mechanical oscillator driven by single-electron tunnelling through a suspended carbon nanotube

Mo. 5.11.18
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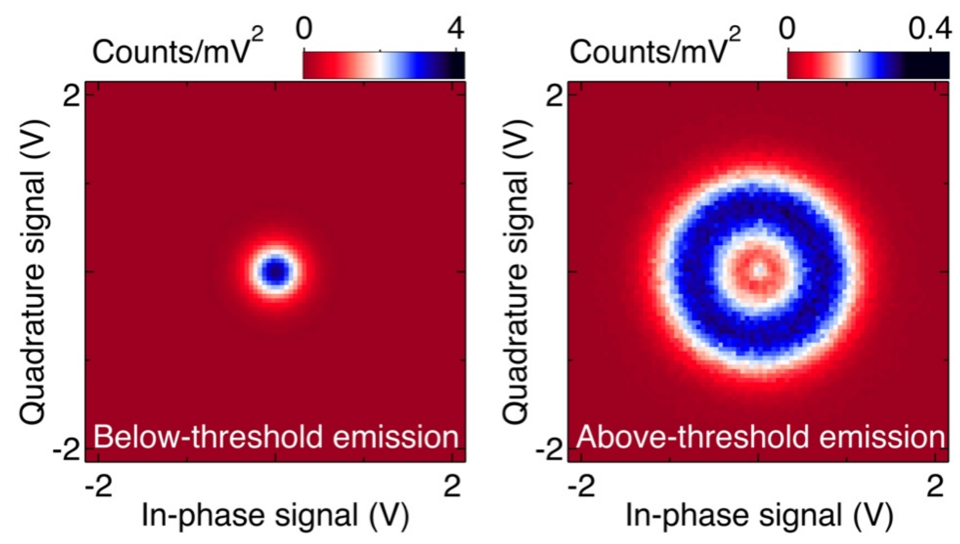
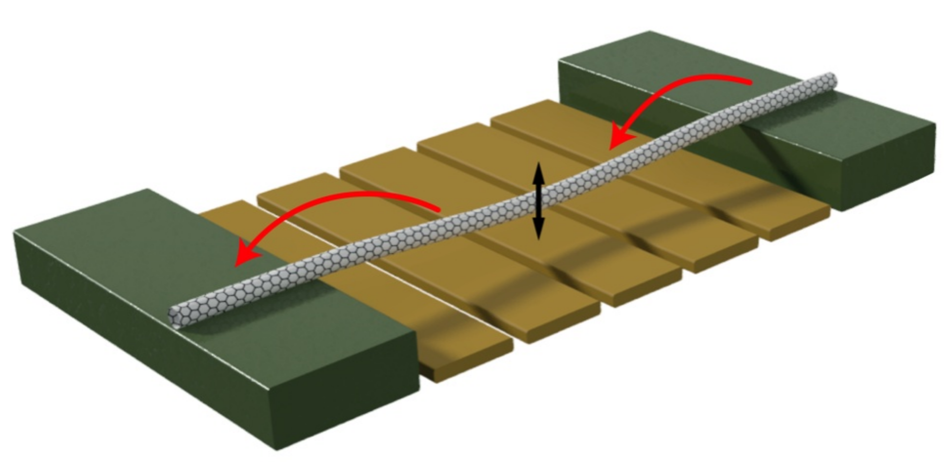
Suspended carbon nanotubes are mechanical resonators with low mass, high compliance, and high quality factor, which make them sensitive electromechanical detectors for tiny forces and masses [1]. These same properties are favourable for studying the effects of strong measurement backaction; indeed, when measuring mechanical vibrations with high precision and speed, the effects of backaction become unavoidable. This talk will describe fast electrical measurements of a vibrating nanotube, and study how electron tunnelling through the nanotube excites spontaneous mechanical oscillations.

Our device consists of a clean carbon nanotube, spanned across a trench so that it is free to vibrate. To monitor the motion, we create a pair of tunnel barriers to define a single-electron transistor, whose conductance is proportional to the displacement. We have implemented a high-speed measurement circuit to measure this rapidly varying signal directly. With low electromechanical coupling, the single-electron transistor is a sensitive transducer of driven mechanical vibrations. At intermediate coupling, electrical backaction damps the vibrations. However, at strong coupling, the resonator can enter a regime where the damping becomes negative; it becomes a self-excited oscillator.



This electromechanical oscillator has many similarities to a maser, with the population inversion provided by the electrical bias and the resonator acting as a phonon cavity. We characterize the resulting coherence and demonstrate other characteristics of maser behaviour, including injection locking and feedback narrowing of the emitted signal.



[1] Ares N, Pei T, Mavalankar A, et al. Resonant optomechanics with a vibrating carbon nanotube and a radio-frequency cavity. PRL 117 170801 (2016)

[2] Wen Y, Ares N, Pei T, Briggs GAD, Laird EA. Measuring carbon nanotube vibrations using a single-electron transistor as a fast linear amplifier. APL 113 153101 (2018)

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