A coherent mechanical oscillator driven by single-electron tunnelling

Dr Edward Laird
Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom

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. These same properties are favourable for studying the effects of strong measurement back-action. This talk will describe fast electrical measurements of a vibrating nanotube in which electron tunnelling excites spontaneous mechanical oscillations.

Our device consists of a clean carbon nanotube, spanned across a trench. A pair of tunnel barriers defines a single-electron transistor, whose conductance is proportional to the displacement. With low coupling, the single-electron transistor is a sensitive transducer of driven mechanical vibrations. At intermediate coupling, electrical back-action 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 laser, 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 laser characteristics, including injection locking and feedback narrowing of the emitted signal.

Reference

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Y. Wen et al., Nat. Phys. **16** 75 (2020)

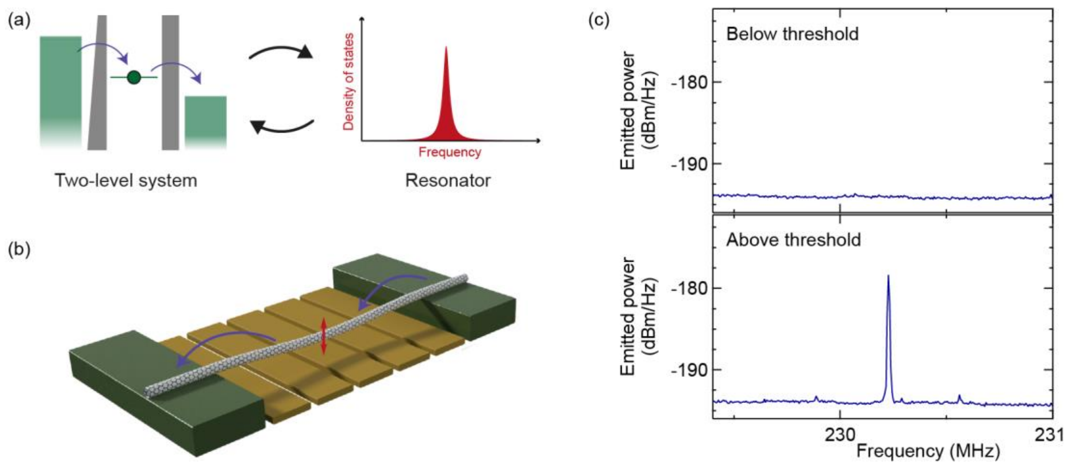

Figure (a) Oscillator schematic. (b) Realization in a vibrating carbon nanotube. (c) Radio-frequency emission for device configurations below and above threshold, showing onset of self-exited oscillations.