Electro-mechanical resonators based on graphene

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Abstract

When a graphene layer is suspended over a circular hole, the graphene vibrates as a music drum. However, such a graphene drum has an extremely small mass. Another difference is the quality factor Q, which becomes extremely large in graphene resonators at cryogenic temperature (Q above 1 million). Because of this combination of low mass and high quality factor, the motion is enormously sensitive to external forces. Here, we couple the graphene resonator to a superconducting cavity via the radiation pressure interaction. The superconducting cavity allows us to transduce the graphene motion with unprecedented sensitivity. We sideband cool the graphene motion to an average phonon occupation that approaches the quantum ground-state. We show that the graphene resonator is a fantastic force sensor with a sensitivity approaching the fundamental limit imposed by thermo-mechanical noise. We find that energy decays in a way that has thus far never been observed nor predicted. As the energy of a vibrational mode freely decays, the rate of energy decay switches abruptly to lower values, in stark contrast to what happens in the paradigm of a system directly coupled to an environmental bath. Our finding is related to the hybridization of the measured mode with other modes of the resonator. Our work opens up new possibilities to manipulate vibrational states, engineer hybrid states with mechanical modes at completely different frequencies, and to study the collective motion of this highly tunable system.

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