Macroscopic manifestation of backaction due to quantum tunneling of electrons

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The wave-particle duality and quantum uncertainty assert a statistical nature to the dynamics of electrons and photons, manifested as measurement noise in the field of sensitive quantum limited measurements. Besides limiting the accuracy of the measurement, this noise also perturbs the state of the system, called backaction.

In this work, we present the effect of quantum noise due to the electron tunneling process in a quantum point contact (QPC) electrical amplifier onto the macroscopic host crystal. The electrical amplifier consists of a semiconducting QPC galvanically coupled to a superconducting λ/2 transmission-line resonator operating at around 2.16 GHz with a conductance sensitivity of about 11 pS/Hz$^{1/2}$. The electron tunneling events exert a backaction noise onto the host GaAs crystal, exciting vibrational modes via the piezoelectric effect. This electromechanical coupling induces characteristic peaks on the noise spectrum corresponding to the piezoelectrically active vibrational modes. From the power spectrum analysis, we are able to detect displacements corresponding to these vibrations with a sensitivity of the order pm/Hz$^{1/2}$. In addition to demonstrating the macroscopic manifestation and microscopic backaction of an ultra-sensitive sensor, this technique allows one to detect mechanical motion with pico-meter level sensitivity at faster timescales.