

Sensing the nanomechanical motion of an electron cluster via an electronic two-level system

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Non-Gaussian quantum states of mechanical motion offer enhanced capabilities for probing fundamental physics and ultraprecise sensing applications. Two ingredients are required to reach this goal: Quantum-limited motion sensing and the ability to create nonlinear states of mechanical motion close to the quantum ground state. Optomechanical systems, on one hand, excel at measurement of mechanical motion, with a precision at the standard quantum limit (SQL) for weak continuous measurement routinely achievable. However, in such systems, the creation of highly nonlinear mechanical states close to the quantum ground state is difficult. On the other hand, mechanical resonators coupled to quantum dots achieve extreme mechanical nonlinearities by coupling to the electronic two-level-system (eTLS). This extreme coupling, however, causes dynamical backaction which greatly degrades the mechanical quality factor, preventing both precise

measurement and quantum state preparation [1].

We have developed an ultraprecise charge-sensing technique which overcomes these challenges and allows measurement of such a system with a measurement precision near the standard quantum limit in the few-phonon limit. This is achieved firstly by employing an RF readout technique without the need for impedance matching. Secondly, we leverage the strong capacitive coupling between the vertical motion of an environmentally decoupled electron cluster in the target system and the charge sensor quantum dot. We implemented the method in a suspended carbon nanotube (CNT), which beats the sensitivity of previous charge/TLS-based vibration measurements. Our approach paves the way for realizing quantum-enhanced mechanical sensing with engineered non-linear mechanical states.

References

- [1] C. Samanta et al, Nature Physics, 19 (2023) 1340

Figures

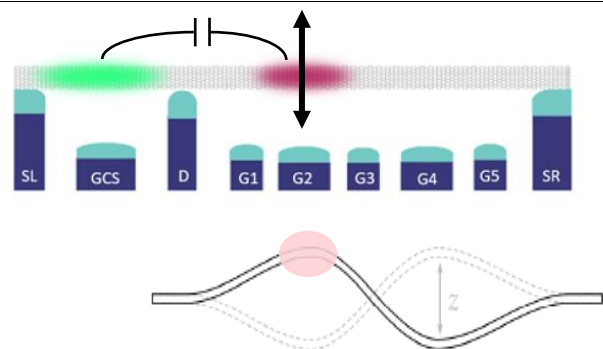


Figure 1: Illustration of the system. Left, green: Charge sensing quantum dot, coupled to the environment and read out via charge transport. Right part: The decoupled quantum dot, or electron cluster, is shown in red. It follows the vertical motion of the CNT (bottom illustration) and is coupled capacitively to the charge sensor.