High-Fidelity Charge Readout and Low-Backaction Nanomechanical Measurement in Suspended Carbon Nanotubes

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We present an ultrasensitive charge-sensing architecture enabling high-fidelity readout of electronic degrees of freedom and low-backaction measurements of nanomechanical motion in suspended carbon nanotube devices. The platform is based on an integrated single-nanotube geometry hosting both gate-defined quantum dots and a proximal charge sensor within the same suspended nanotube.

A radio-frequency readout scheme operating without impedance matching is employed, overcoming a key limitation of conventional reflectometry while preserving a simple experimental implementation. The drain of the charge sensor is coupled to an RLC resonator with a resonance frequency of approximately 1.25 MHz, enabling single-shot charge readout with exceptionally high fidelity for microsecond integration times, surpassing the state of the art by more than one order of magnitude.

Beyond charge detection, the same sensor provides sensitive access to the mechanical degrees of freedom of the suspended nanotube by transducing displacement into conductance variations. Operating in a regime of strongly suppressed measurement backaction and ultrastrong electromechanical coupling, this platform enables quantitative nanomechanical spectroscopy and opens the way to exploring new fundamental physics, including macroscopic superposition of mechanical states and quantum simulation in carbon nanotube systems.

References

[1] A. Bachtold et al., Reviews of Modern Physics, 94 (2022) 045005
[2] R. J. Schoelkopf et al., Science, 280 (1998) 1238

Figures

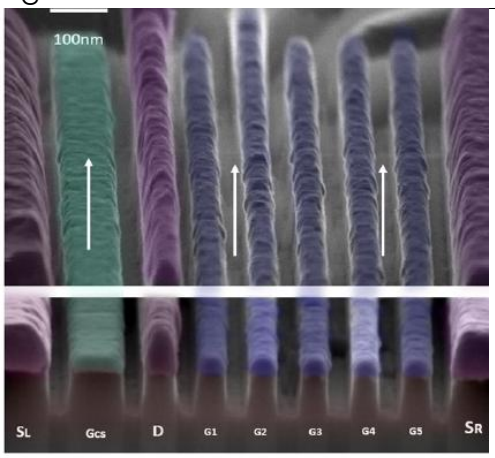

Figure 1: SEM imagine of the device.

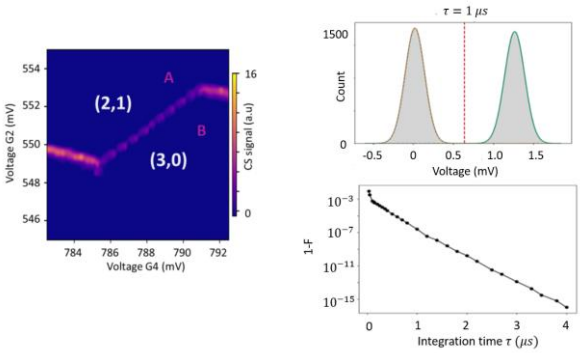

Figure 2: Single-shot charge readout fidelity and The two different states.