Nonlinearities in Carbon Nanotube mechanical resonators in the quantum regime

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Carbon nanotube (CNT) resonators, with their unique combination of large zero-point motion, tunable quantum dots, and high mechanical quality factors, provide an exceptional platform for investigating non-linear quantum dynamics [1,2]. We investigate how coupling the flexural modes of suspended CNTs to double quantum dots (DQDs) reshapes the effective mechanical potential and modifies the dynamics of the system [1,3,5]. The system is designed to operate in the ultrastrong coupling regime, where the interaction strength surpasses the mechanical frequency, inducing significant non-linearities in the mechanical potential, opening new opportunities in quantum information and sensing. We employ a cavity reflectometry-based readout to probe the system, enabling precise characterization of the quantum state of the CNT resonator and its interaction with the DQD.

Our work focuses on three key aspects: controlling critical parameters of the double quantum dot qubit such as tunneling strength between the two dots and energy detuning between left and right dots; minimize decoherence sources like thermal noise and detuning drifts to preserve quantum coherence [4]; and conducting experiments at cryogenic temperatures to measure resonance frequencies and explore the transition to a double-well.

These studies not only deepen our understanding of quantum mechanical non-linearities but also provide the foundation for future developments in mechanical qubits, hybrid quantum systems, and advanced quantum sensing technologies.

References

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Figures

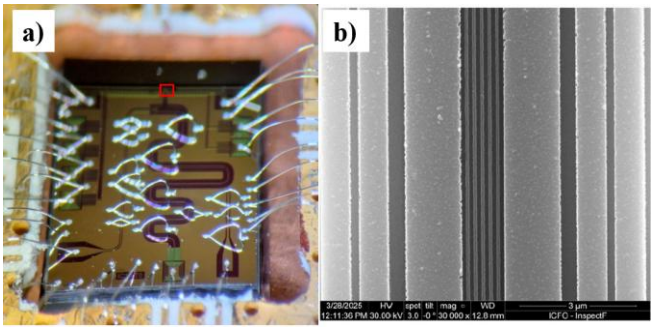

Figure 1: a) Picture of a integrated multigate-cavity chip. The chip is fabricated on a Si/SiO_2 substrate with Nb gates electrodes and cavity, and Pt source and drain. Each electrode (source, drain and gates) has an LC filter. b) Zoom-in Scanning Electron Microscope (SEM) picture of the red square region of a). The CNT is stamped and remains suspended over the five gate electrodes shown in the image. We can see 5 gate electrodes in the center, source and drain to the side of the gates and two extra electrodes on each side to assist in the stamping method.