Development of Nano Electromechanical Devices for Quantum Ground State Cooling

CNF Project # 1480-06

Principal Investigator(s): Prof. Keith C. Schwab

User(s): Jared B. Hertzberg, Tchefor T. Ndukum, Tristan O. Rocheleau

Affiliation(s): 1. Physics Department, Cornell University; 2. Physics Department, University of Maryland

Primary Research Funding: Start up

Contact: schwab@ccmr.cornell.edu, jaredh@umd.edu, ttn22@cornell.edu, tor2@cornell.edu

Abstract:

We have fabricated nanomechanical resonators embedded in a superconducting microwave cavity on a silicon chip. Capacitive coupling between the mechanical and electrical resonances enables the electromagnetic wave to act on the mechanical motion and vice versa. At cryogenic temperatures, careful driving and probing of the microwave field should enable near-quantum-limited position detection as well as cooling the mechanical device to the quantum ground state of its motion. Such a result would shed light on the transition between classical and quantum behavior of mechanical systems.

Summary of Research:

In this project we attempt to cool a mechanical device to its quantum ground state by carefully driving and probing it in a microwave cavity [1-4]. At low temperatures, this can be achieved by applying a pump signal that is red detuned from the microwave cavity. This will favor the absorption of quanta from the mechanical device (by the cavity) leading to its cooling. By using a high Q mechanical device with resonant frequency larger than the linewidth of the microwave cavity, it should be possible for the cavity to remove nearly all the quanta from the mechanics faster than it is being replenished by the cryogenic environment. The cooled mechanical device should be a near-quantum-limited position detector.

We have designed and fabricated nanomechanical (NR) beams that are capacitively coupled to a superconducting microwave coplanar waveguide (SCPW) [5-6]. The fabrication was done at the Cornell NanoScale Facility (CNF) clean room. The beams are doubly clamped and were made of 50-100 nm thick aluminum deposited on 70 nm thick high-stress low pressure chemical vapor deposition (LPCVD) silicon nitride (Figure 1 and 2). The SCPWs were fabricated using standard photolithography while the NR beams were written by electron beam lithography. The beams were released...
by two consecutive reactive ion etch (RIE) processes, one to vertically etch the nitride layer and the second to isotropically remove the silicon underneath the beams. Freed beams are usually 60-120 nm from a gate in electrical contact with the center line of the SCPW (Figure 2).

We have studied the resonant properties of SCPW at mK temperatures (Figure 3). We have measured the coupling strength of the NR beams to these SCPW. From the temperature calibration of the power spectrum of the NR beam in the cavity we have been able to estimate the mechanical noise of the sidebands at low temperatures (Figure 4).

References: