Annual Progress Report 2013-2014

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1. Research Goal

The goal of my research project is to achieve pulsed optical control of Optomechanical systems via Quantum Non-demolition (QND) interaction between optical phase quadrature and mechanical position. Such pulsed interaction is theoretically shown to realize Back-action Evading Readout of the mechanical states beyond Standard Quantum Limit (SQL), therefore allowing Quantum State Tomography and the projection of mechanical states into quantum states including squeezed states and the ground state.

2. Progresses 2013-2014

Nano-fabrication of Optomechanical Device

Together the Painter group at Caltech, we fabricated on-chip Si3N4 optoemchanical devices (see Figure 1a) with cavity-enhanced optomechanical intercations (g_0>0.1 MHz) and higher mechanical quality factors (Q_m> 10^6), and optical linewidth (κ) of ~ 2 GHz.

High-speed Optical Homodyne Detection

In order to detect short optical pulses (< 10 ns), we implemented optical homodyne detection setup with the bandwidth from DC to 400 MHz and the optical shot-noise-limited noise performance at 0.5 mW intensity. In addition, we integrated an interferometer-stabilizing feedback lock to ensure the same optical homodyne phase angle over long repetitive measurements.

High-power Narrow-linewidth Laser Amplifier

In order to increase measurement sensitivity beyond SQL, high-power (total > 50 mW; > 5 mW to the device input and > 45 mW as the local oscillator) laser is required. To realize such high intensity together with low noise performance (i.e. narrow linewidth), we combined conventional optical amplifier (> 1000 mW) and the narrow linewidth (< 10 MHz) filter cavity. To that end, we achieved > 100 mW total power and ~ 10 MHz linewidth as the output laser.

Preliminary (thermal) squeezing experiment

To evaluate the principle of our experiment, we applied our pulsed scheme (with a low pulse peak-power ~ 0.1 mW) to one of the fabricated devices (see Figure 1b). Here, we observed squeezing of mechanical position by a factor of 4.5 squeezing from the thermal state at room temperature (300 K). We also independently measured our detection noise floor of 0.3 mV. The source of remaining signal at squeezing (7.8 mV) is the motions of other mechanical modes in the device.

Low-power Continuous Homodyne Readout of the other mechanical modes

Currently, our measurement is limited by additional noise arising from multitude of mechanical modes of the devices. To effectively suppress those effects, we are currently incorporating weak measurement of the other modes via low-power continuous homodyne and their linear quadratic estimation (Kalman filter).

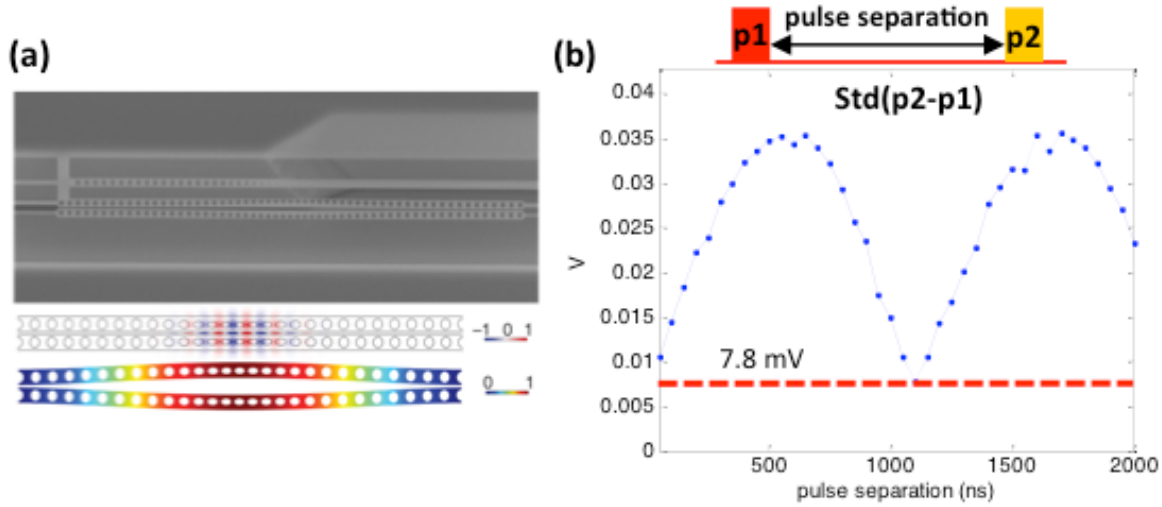

Figure 1. (a) Fabricated Si3N4 Optomechanical device. (b) Thermal squeezing of mechanical position via two-pulse scheme.

3. Future Plan

For the final goal of the research, we plan to incorporate continuous weak measurement of the other mechanical modes followed by pulsed measurement. Finally, by integrating high-power narrow-linewidth optical amplifier setup, we will achieve strong enough optical pulse power, thus paving the way towards QND detection of mechanical positions below SQL and generation of quantum squeezed mechanical states.