Approaching quantum operation of a microwave-mechanical-optical transducer


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Viewed as resources for quantum information processing, microwave and optical fields offer complementary strengths. Whereas in the microwave domain quantum information can be flexibly manipulated and stored, in the optical domain quantum information can be efficiently transported over kilometer distances, and at ambient temperatures.

Motivated by these observations, we aim to create a quantum-compatible link between microwaves and optics using a mechanical resonator. An appealing application of this link would be creating a quantum network of optically-connected superconducting circuits. Such a network could transmit information with security guaranteed by physical laws, realizing a longstanding ambition of quantum information science.

Our approach is to simultaneously couple one mode of a micromechanical oscillator to a resonant microwave circuit and a high-finesse optical cavity (Fig. 1a). In previous work, this system was operated as a classical converter between microwave and optical signals at 4 Kelvin, operating with 10% efficiency and 1500 photons of added noise [1]. If operated in the quantum regime, unity efficiency and noiseless conversion are theoretically possible.

In this talk, I will discuss our efforts to operate a microwave-mechanical-optical transducer in the quantum regime. To improve transfer efficiency, we have implemented wireless microwave access to the converter chip. To improve noise performance, we now operate the converter at 0.1 Kelvin. We have measured transfer efficiency in this regime, observed order-of-magnitude improvement in noise performance, and quantified effects from undesired interactions between the laser and superconducting circuit. Classical correlations between the microwave and optical fields have also been investigated, serving as a precursor to upcoming quantum operation (Fig. 1b).

Figure 1. a Mechanical oscillator simultaneously coupled to resonant microwave circuit and optical mode. b Optics y-quadrature vs microwave x-quadrature. Quadrature noise is uncorrelated with pumps off, but correlated with pumps on.