Coupling macroscopic membrane resonator modes with three dimensional microwave cavity modes

Jingwei Zhou and Mika Sillanpää

Department of Applied Physics, Aalto University, P.O. Box 15100, FI-00076 AALTO, Finland
email: jingwei.zhou@aalto.fi

Cavity optomechanics allows us to cool the mechanical resonators into ground state now[1, 2, 3]. Applications such as sensitive detection, quantum information processing and fundamental quantum theory test are developed. However, observation of quantum entanglement between two macroscopic mechanical oscillators is still very challenging.

Here we integrate high tension silicon nitride membrane into three-dimensional superconducting microwave cavity. To couple the motion of membrane with the cavity field, we flip the metalized membrane chips and assemble to the antenna chips. We etch the silicon of antenna chips for more than 10 micrometers to prevent any dirty particle during the wafer bonding process. With this method, the gap is minimized to several hundred nanometers. The single photon coupling strength can be several tens Hz with such small gaps. We put the 3D cavity assembly into dilution refrigerator and extract the mechanical motion of the membrane by measuring the reflection coefficient of the cavity. The mechanical quality factor of the membrane is about 2.2×10^7 with its frequency 700 kHz. Our 3D cavity optomechanical system allows for coupling the mechanical vibrations simultaneously to multiple cavity modes. Two mechanical membranes can also be coupled mediated by cavity fileds.

Such 3D architecture quantum system provides a new route for the entangling two mechanical resonators and the detection of such entanglements. It can also be used to study complex quantum dynamics and simulate many body quantum phenomenon[4].

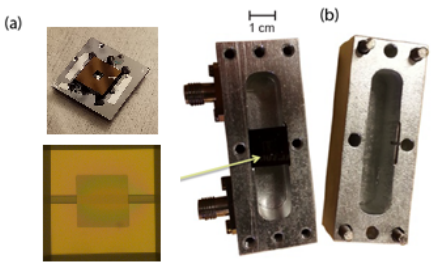

Figure 1: SiN membrane assembly, and a three-dimensional cavity

[1] A. D. O'Connell et al., Nature 464, 697 (2010)
[2] J. D. Teufel et al., Nature 475, 359 (2011).
[3] J. Chan et al., Nature 478, 89 (2011).
[4] R. Süsstrunk and S. D. Huber, Science, 349, 47 (2015).