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Investigation of mechanical modes coupling in silicon nitride drum resonators at room temperature

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Silicon nitride (SiN) micro electromechanical system (MEMS) is one of the good candidates for sensing and signal processing because of its high-quality factor and mechanical properties [1]. Here, we present our recent work in studying mechanical modes coupling by using SiN based MEMS. The MEMS used in our experiment is a SiN drum covered with an Al thin layer, capacitively coupled to a suspended Al top-gate [2]. It is fabricated by a standard top-down nanofabrication process. The ultra-clean fabrication process allows to have a high- quality factor, Q_c~10^4 at the room temperature. We use microwave reflectometry to detect the mechanical modes $\Omega_{n,m}$ of the drum resonator by using an ac signal to excite its mechanical motion. The suffixes *n,m* refer to azimuthal and radial modes, respectively. For a drum with a diameter of ~ 30 µm, three mechanical modes $\Omega_{0,1}\sim 11\ MHz$, $\Omega_{1,1}\sim 19\ MHz$ and $\Omega_{0,2}\sim 27\ MHz$ have been observed.

In order to understand the mode coupling in this MEMS, we choose $\Omega_{0,2}$ as the phonon cavity and use side-band pumping technique to pump the phonon cavity at the frequency, $\omega_p = \Omega_{0,2} + \Omega_{0,1}$ (blue side-band) or $\omega_p = \Omega_{0,2} - \Omega_{0,1}$ (red side-band) and use a very small RF signal to probe the cavity [3, 4]. Because of the nonlinearity induced mode-mode coupling, a splitting phenomenon in mode $\Omega_{0,2}$ has been observed as shown in **Figure 1**. Similar to the optical damping effect in optomechanics, the damping rate of the first mode $\Omega_{0,1}$increases with increasing the pumping power when the phonon cavity is pumped at the red side-band and decreases when the cavity is pumped at the blue side band. Besides, we also investigate capacitive coupling between the mode $\Omega_0\sim 3\ MHz$ (Q ~300) coming from the suspended Al top gate and the mechanical modes from the SiN drum, exhibiting a different kind of coupling mechanism. In brief, our high-Q drum resonator with large capacitive coupling scheme allows to study mechanical modes coupling which could serve for both classical and quantum engineering.

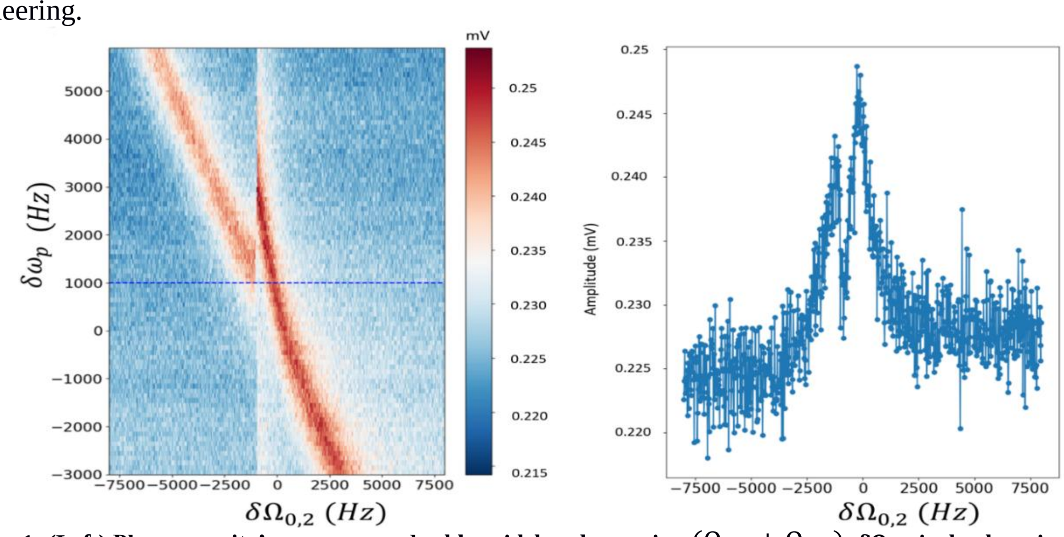

Figure 1: (Left) Phonon cavity's response under blue sideband pumping $(\Omega_{0,2} + \Omega_{0,1})$, $\delta\Omega_{0,2}$ is the detuning from the resonant frequency $\Omega_{0,2}$ and $\delta\omega_p$ is the detuning from the pump frequency, $\omega_p = \Omega_{0,2} + \Omega_{0,1}$. (Right) the profile of the splitting phenomenon taken from the horizontal line (dashed blue) on the left figure.

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