# High-Q Nanomechanical Resonators as Force Sensors and Synthetic Two Level Systems

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Abstract

In the first half of this contribution [1], we demonstrate that soft-clamped silicon nitride strings with large aspect ratio can be operated at mK temperatures. The quality factors (Q) show consistent dependency on the cryostat temperature, with soft-clamped mechanical modes reaching $Q > 10^9$ at 80 mK. For low optical readout power, Q is found to saturate, indicating good thermalization between the sample and the stage it is mounted on. Our best device exhibits a force sensitivity of 12.6 zN/√Hz and a thermal decoherence time of 0.22 s which bode well for future applications such as nanomechanical force sensing and beyond. We also elaborate on potential next steps on performing force sensing using high-Q perimeter mode resonators with integrated optical cavities.

In the second half [2], we study the Kerr Parametric Oscillator as an approximation to a synthetic two-level system. In the presence of strong noise, the system switches between two states via a fluctuating trajectory in phase space, instead of following a straight path. The presence of such fluctuating trajectories makes it hard to establish a precise count, or even a useful definition, of the ``lifetime'' of the state. Addressing this issue, we compare several rate counting methods that allow to estimate a lifetime for the levels. In particular, we establish that a peak in the Allan variance of fluctuations can also be used to determine the levels' lifetime. Our work provides a basis for characterizing KPO networks for simulated annealing where an accurate determination of the state lifetime is of fundamental importance.

References

[1] arXiv:2112.03730
[2] arXiv:2112.03357

Figures

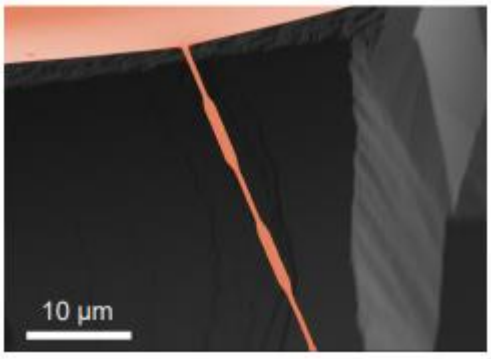


**Figure 1:** A false-colored SEM image of a high-Q nanomechanical string device. Shown is one clamping point and two unit cells.

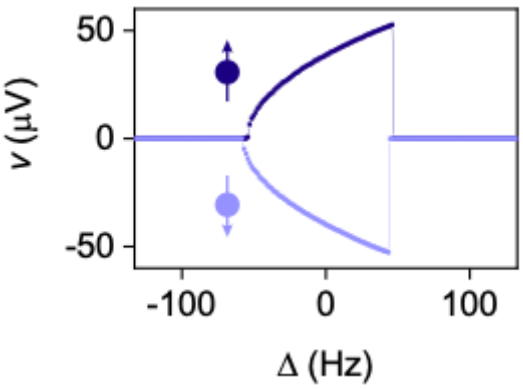


**Figure 2:** Measured out-of-phase response *v* of the resonator to parametric driving as a function of detuning.