Keynote

Coherent control of nanoelectromechanical systems

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Nanomechanical resonators are freely suspended, vibrating bridges with nanoscale diameters. These nanostructures are receiving an increasing amount of attention, both in fundamental experiments addressing the foundations of quantum mechanics and for sensing applications, and show great promise as linking elements in future hybrid nanosystems.

In particular, doubly-clamped pre-stressed silicon nitride string resonators are explored as high Q nanomechanical systems enabling room temperature quality factors of several 100,000 in the 10 MHz eigenfrequency range. Electrically induced gradient fields are employed to implement dielectric trans-duction as an efficient way to actuate and probe these nanostrings and to tune their eigen¬frequencies over a wide frequency range [1,2]. The two orthogonal fundamental flexural modes of the string vibrating in- and out-of-plane with respect to the sample surface can be engineered to tune in opposite direction. Thus, both modes can be brought into resonance where a pronounced avoided crossing is observed, indicating that the mechanical modes are strongly coupled.

A pulsed measurement scheme is used to analyze the time-dependent evolution of a previously initialized mode as it is tuned across the coupling region. At slow sweep rates, the system adiabatically follows the energy eigenstates, whereas the energy is transferred from one branch to the other during fast sweeps. The measured classical transition probabilities show excellent agreement with Landau-Zener theory [3]. Furthermore, the demonstrated time-domain control allows deep insights into the nanomechanical classical two-mode system defined by the lower and upper hybrid mode of the avoided crossing. To this end electromagnetic pulse techniques well known from coherent control of two-level systems in atoms, spin ensembles, or quantum bits and the corresponding Bloch sphere picture are introduced to nanomechanical systems [4]. Full Bloch sphere control is demonstrated by Rabi, Ramsey and Hahn echo experiments. Moreover, we find that all relaxation times T_1, T_2 and T_2* are equal. This not only indicates that energy relaxation is the dominating source of decoherence, but also demonstrates that reversible dephasing processes are negligible in such collective mechanical modes. We thus conclude that not only T_1 but also T_2 can be increased by engineering larger mechanical quality factors. After a series of ground-breaking experiments on ground state cooling and non-classical signatures of nanomechanical resonators in recent years, this may be of particular interest for quantum nanomechanical systems in the context of quantum information processing.

References

[1] Q. P. Unterreithmeier et al., Nature 458, 1001 (2009).
[2] J. Rieger et al., Appl. Phys. Lett. 101, 103110 (2012).
[3] T. Faust et al., Phys. Rev. Lett. 109, 037205 (2012).
[4] T. Faust et al., Nature Physics 9, 485 (2013)

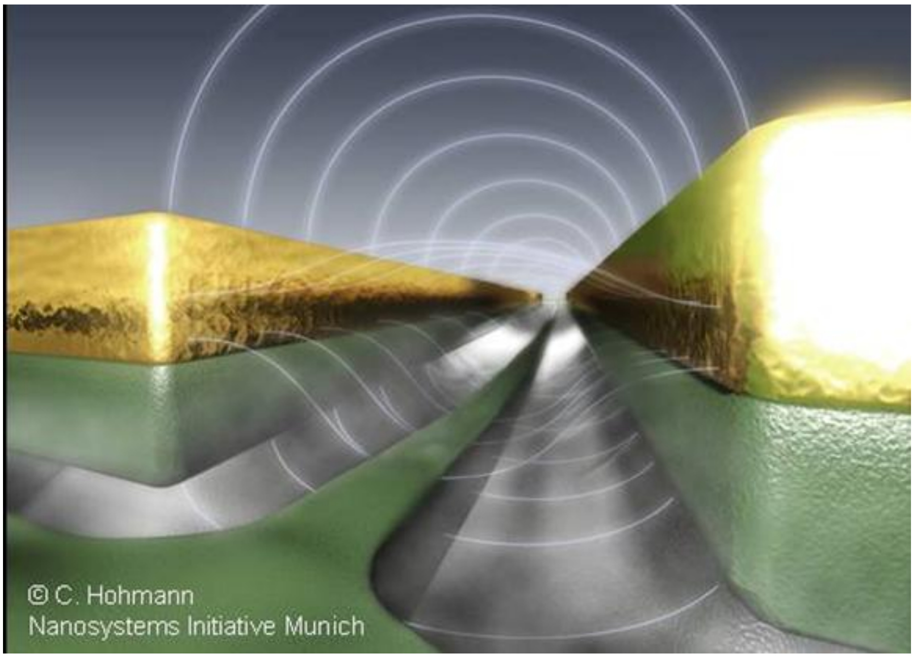

Figure 1. Schematic of nanomechanical string resonator dielectrically coupled to a set of gold electrodes.