Silicon nitride membranes: jack of all electromechanical trades

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The fields of opto- and electro-mechanics are rapidly growing, with impressive results such as ground state cooling [1,2] already achieved. The full potential of this new fields lays in using mechanical vibrations as a "Universal Serial Bus" for quantum objects, towards the ultimate goal of building hybrid systems for an improved quantum technology. Main challenge to this ambitious goal is to build a platform where two or more quantum systems couple strongly to a common mechanical element without spoiling their own individual characteristics. To this end, silicon nitride offers extraordinary capabilities: it is a low-loss, high index material in the NIR while keeping a low loss tangent in the RF range and it is therefore able to work with metallic superconductors. Further, and even more importantly, Si_3N_4 possesses remarkable mechanical properties, thanks to its tensile stress which allows one to produce structures with incredible aspect ratios. Exploiting these features, I will show how silicon nitiride membranes can be used to host electromechanical superconducting LC resonators based on Al, where ground state cooling of a capacitively coupled, low-frequency flexural mode of a nanobeam has been achieved, as well as field-enhanced strong coupling [3].
Starting from this point, I will present some perspective results to couple silicon nitride membranes to molecular spins through a RF, superconducting (high-T_c) resonator, with the possibility of employing the long mechanical lifetimes as memories for spin-based qubits. Moreover, I will show how the tensile pre-stress of silicon nitride can be fully exploited not only to realize linear capacitors with small gaps, but even to perform strain engineering on planar materials deposited on top of the membrane, in particular towards the realization of triaxial strain and pseudo-magnetic fields in graphene monolayers.

References

[1] J. D. Teufel et al., Nature 475 (2011) 359

[2] J. Chan et al., Nature 478 (2011) 89

[3] J. M. Fink, M. Kalaee, A. Pitanti et al., Nat. Comm. 7 (2016)12396

[4] A. Ghirri et al., Appl. Phys. Lett. 106, (2015) 184101

Figures

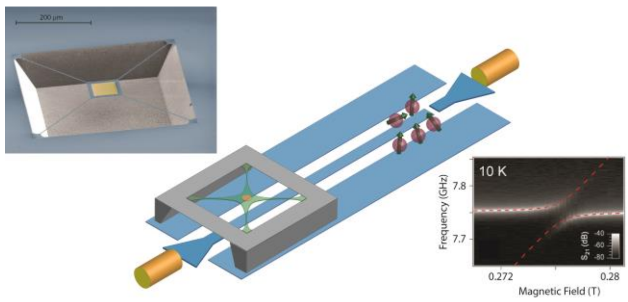

Figure 1: Quantum hybrid system: a silicon nitride trampoline membrane and an ensemble of molecular spins are coupled to the same coplanar waveguide resonator. Spins and photons have already shown strong coupling (colormap in figure) at high-T (from [4]).