Quantum Control of Mechanical Oscillators

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We present experimental and theoretical progress within the rapidly advancing field of quantum control of mechanical oscillators. Firstly, we report on recent experimental results [1] demonstrating quantum enhanced feedback cooling of a micro-mechanical oscillator [2, 3]. Using phase squeezed probe light, the mechanical oscillator displacement is transduced in real-time with a sensitivity 1.9 dB below the shot noise limit (Fig. 1), achieving a 50% improvement of the measurement rate and thereby an enhanced cooling rate compared to coherent light probing.

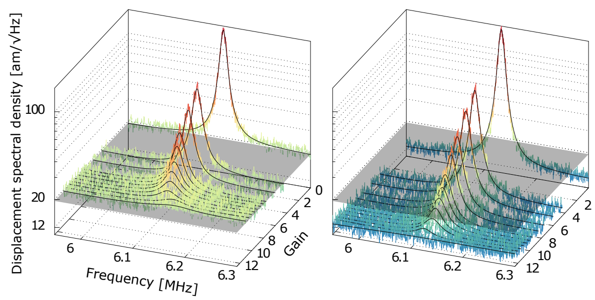

Fig. 1. Experimental feedback cooling of a mechanical oscillator using coherent (left) and phase squeezed light (right).

Secondly, we discuss a proposal for generation of quantum superpositions of macroscopically distinct states of a bulk mechanical oscillator (Fig. 2). Exploiting displaced non-Gaussian quantum states of light in conjuction with an optomechanical quantum non-demolition interaction and measurement-induced feedback, our scheme [4] crucially circumvents the technically challenging need for high single-photon interaction strength [6]. A feasibility study of the scheme reveals that mechanical states with high degree of macroscopicity [5] can be generated under realistic experimental conditions using existing optomechanical and quantum optical resources.

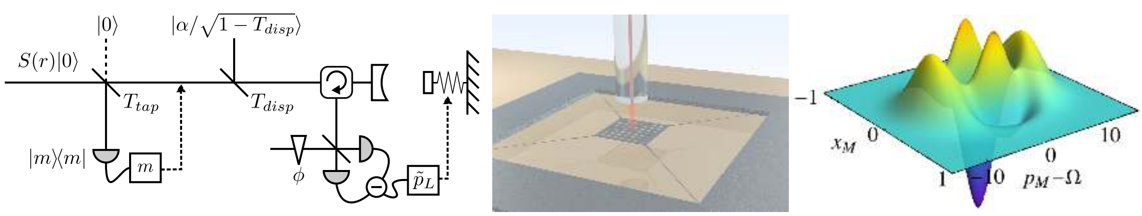

Fig. 2. (left) Proposed scheme for generation of macroscopic superposition states of a mechanical oscillator, (middle) visualisation of envisioned host system, and (right) Wigner function representation of the final mechanical superposition state.

REFERENCES

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[1] C. Schäfermeier, H. Kerdoncuff, U. B. Hoff, H. Fu, A. Huck, J. Bilek, G. I. Harris, W. P. Bowen, T. Gehring, and U. L. Andersen, Nat. Commun. **7**, 13628 (2016)
[2] C. Genes, D. Vitali, P. Tombesi, S. Gigan, and M. Aspelmeyer, Phys. Rev. A **77**, 033804 (2008)
[3] K. H. Lee, T. G McRae, G. I. Harris, J. Knittel, and W. P. Bowen, Phys. Rev. Lett. **104**, 123604 (2010)
[4] U. B. Hoff, J. Kollath-Bönig, J. S. Neergaard-Nielsen, and U. L. Andersen, Phys. Rev. Lett. **117**, 143601 (2016)
[5] C. W. Lee and H. Jeong, Phys. Rev. Lett. **106**, 220401 (2011)
[6] S. Bose, K. Jacobs, and P. L. Knight, Phys. Rev. A **56**, 4175–4186 (1997)