SEMINAR: Investigation of phase diffusion in a single driven nonlinear nanomechanical mode

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12:00 to 13:00
Mir-Puig Seminar Room (MP210)

Doubly-clamped nanostring resonators excel as high Q nanomechanical systems enabling room temperature quality factors of several 100,000 in the 10 MHz eigenfrequency range. Dielectric transduction via electrically induced gradient fields provides an integrated control scheme while retaining the large mechanical quality factor [1]. Dielectrically controlled nanostrings are an ideal testbed to explore a variety of dynamical phenomena ranging from multimode coupling to coherent control [2]. Here we will focus on the nonlinear dynamics of a single, resonantly driven mode.

Under strong driving conditions, we observe an onset of self-sustained oscillation in the rotating frame. This phenomenon can be attributed to a resonantly induced negative effective friction force (RIFF) induced by the drive. The high anharmonicity of the limit cycles manifests in the generation of a nanomechanical frequency comb in the power spectrum [3, 4]. The frequency comb is centered around the forced vibrations initiated at the drive frequency, while the number and spacing of comb lines can be controlled by the drive detuning and power. To account for a non-zero linewidth of the comb lines, we extended the theoretical model to include thermal-motion induced phase diffusion. This results in sub-Hz Lorentzian comb lines and predicts an increasing linewidth from the center to the edges of the comb, scaling quadratically with the comb line index. To experimentally access the shape of the comb lines, we have improved our measurement scheme, which was previously limited to a spectral resolution of 1 Hz. This allows us to capture the true form of the comb lines with mHz resolution, and to study their linewidth. We find linewidths in the sub-Hz range, confirming the predicted scaling with the comb line index. However, our experimental curves cannot be described by the predicted Lorentzian lineshape. This is a clear indication that the phase fluctuations are not only caused by thermal white noise, but also by a mechanism with a longer time correlation. We are currently working on an extended theory to include other possible phase diffusion mechanisms.

Thus, taking advantage of self-sustained oscillations in a single driven nonlinear nanomechanical mode, we explore phase diffusion in nanomechanical resonators. As the diffusion mechanism manifests in the spectrum of a single driven mode, this technique presents an orthogonal approach to previous work that relied on backaction or parametrically coupled modes to induce self-sustained oscillations [5]. We expect novel insights into the nature of phase diffusion and its underlying microscopic mechanisms.

[1] Q. P. Unterreithmeier et al., Nature, **458**, 7241 (2009).
[2] T. Faust et al., Nat. Phys. **9**, 485-488, (2013).
[3] J. S. Ochs et al., Phys. Rev. X **12**, 041019 (2022).
[4] M. I. Dykman et al., Phys. Rev. Lett. **122**, 254301 (2019).
[5] F. Sun et al., Nat. Commun. **7**, 12694 (2016).

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Hosted by: Prof. Dr. Adrian Bachtold