Visualization of Spatial Modulation and Persistent Response States of Strongly-driven Membrane Resonators

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Title: Visualization of Spatial Modulation and Persistent Response States of Strongly-driven Membrane Resonators.
Micro- and nano-scale mechanical resonators operated in the nonlinear regime exhibit unusual dynamic behavior, e.g. the phenomenon of persistent response, which denotes the development of a vibrating state with nearly constant and high amplitude over a wide frequency range, see Fig. 1 left. So far, the requirements and the underlying mechanism to obtain the persistent response state have been unclear, mainly because of the difficulties to characterize this complex vibrational state experimentally. Here we present a method based on optical interferometry to directly image the vibrational state of membrane resonators. We show that upon increasing the driving strength the membrane first adopts a deflection pattern determined by localized, ring-shaped overtones of the driven mode (Fig. 1 middle) and that we denote as spatial modulation. At even larger driving strength, the persistent response arises as a signature of mode coupling between different flexural modes and their localized overtones, see Fig. 1 right.

Persistent response and spatial modulation: Left, four nonlinear resonance curves generated by different excitation voltages showing the mean amplitude response averaged over the whole membrane area. Two distinct frequency ranges are separated by a dashed line and are marked as I and II. Middle: Four examples of spatial deflection patterns observed at different driving frequencies $f_d$ in range I associated with the spatial overtones of the ground mode mode. Right: Zoom into range II. The amplitude forms a plateau, but reveals small steps and kinks in the saturated area, some of them being marked by colored areas. In these areas the evolution of different mode patterns is captured. The red arrows indicate the position where the deflection patterns were captured.

We propose a phase diagram for the manifold vibrational states that the membrane can adopt and a model based on the coupling of nonlinear oscillators that qualitatively...
describes the experimental observations.