# Harnessing non-linear effects for mesoscale devices

## Opportunity

Most micro- and nanoscale mechanical, electronic, and optical devices are operated with careful control to guarantee operation in the linear domain of their response and to avoid nonlinear regimes where responses become more complex. However, nonlinear responses offer unique possibilities for controlled response and novel applications. Examples include parametric amplifiers, self-stabilizing oscillators, sensitive optical switches, and enhanced sensors. Today there are very few efforts to understand and leverage nonlinear phenomena in micro- and nanosystems.

## Meso Challenge

Nonlinear responses, frequently enhanced at the nanoscale, offer a unique opportunity to function as a switch mechanism to controllably couple different forms of energy (charge, photons, mechanical) from the nanoscale into the mesoscale. Challenges to achieve this goal include:

- How to best harness the nonlinear properties rather than working around them.
- How to analyze and model nonlinear behavior.
- How to couple nonlinear devices.

## Approach

- Design and build meso- and nanoscale devices that can be operated in the nonlinear regime.
- Studying the nonlinear response of these devices
- Graphene can be deformed well into the nonlinear regime while maintaining its atomically perfect nanostructure. Exploit how Graphene's superior mechanical properties could be imbedded into meso-scale nonlinear devices.
- Develop efficient nanoscale optical nonlinear materials for switching and parametric amplification techniques.

## Impact

- Developing a complete understanding of the fundamental processes that govern the nonlinear dynamics of meso-scale devices and create models that are capable of predicting nonlinearities.
- Use nonlinearities to couple optical and mechanical energy from the nanoscale into the mesoscale.
- Moreover, go beyond the basic science to identify compelling high-payoff applications by utilization of nonlinear dynamics in mesoscale structures.

References: D. Antonio (CNM), D. Zanette (CNICT Argentina), D. López (CNM), Frequency stabilization in nonlinear micromechanical oscillators. *Nature Communications*, 3:806 (2012) doi: 10.1038/ncomms1813

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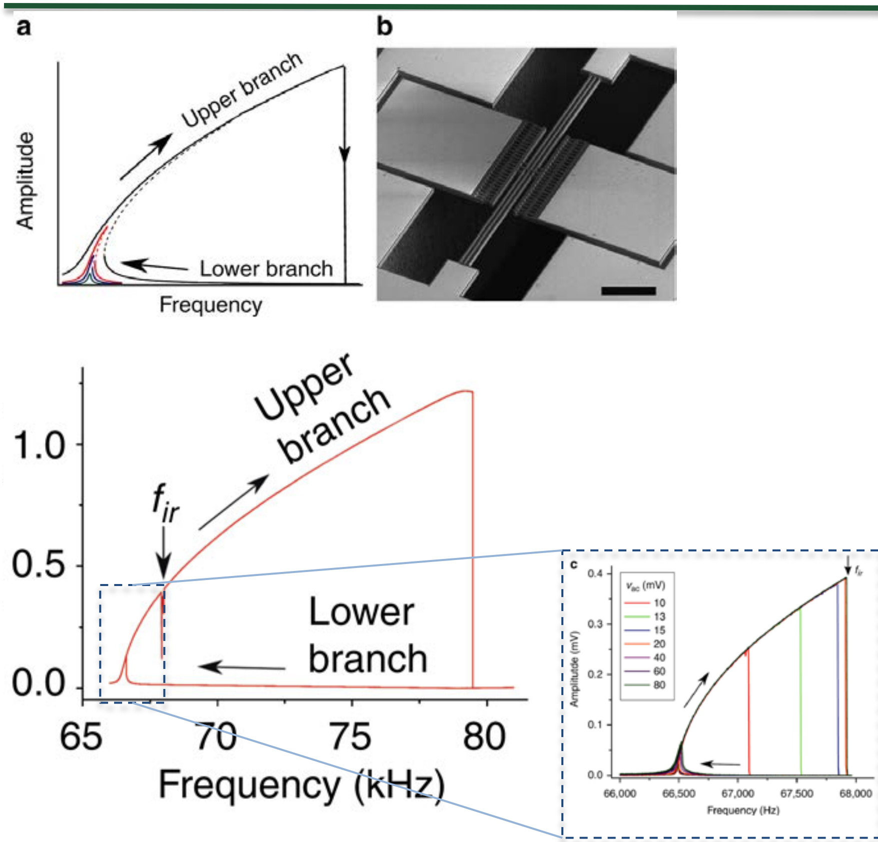
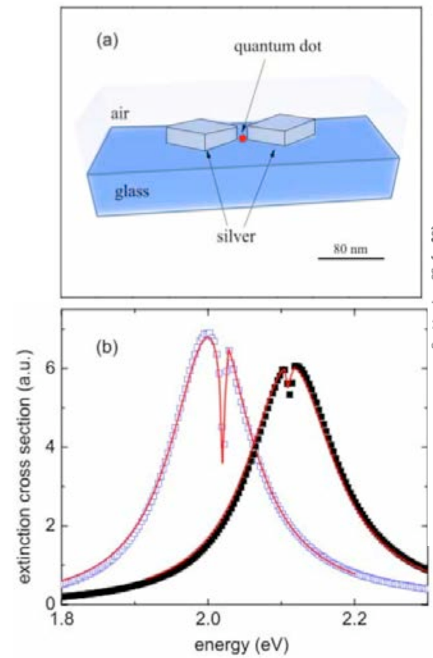
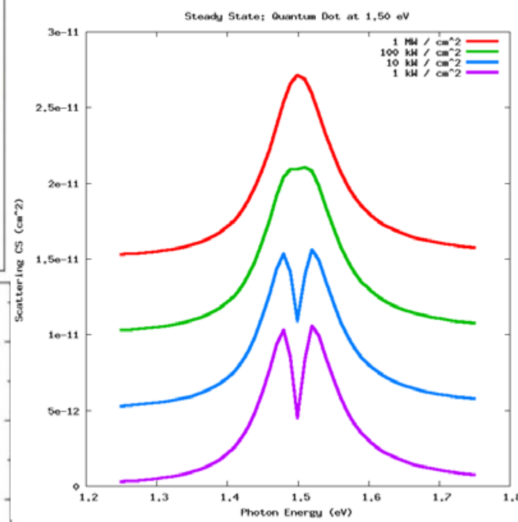



Frequency stabilization in nonlinear nano-mechanical oscillator via coupling to different vibrational modes through internal resonance. This result demonstrates that very low-frequency noise performance is possible in the nonlinear regime.




*Coupled plasmonic-quantum dot nanoparticle systems (left) show unique optical transparencies (X. Wu, S. Gray, and M. Pelton, Optics Express **18**, 23633 (2010)). These transparencies are predicted to respond nonlinearly to incident light (right), thus opening a means for an optically controlled switch of photon flow from the nanoscale to the mesoscale.*

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