Nonlinear dynamics and chaos in Optomechanical nanobeams

D. Navarro-Urrios[1,2], N. Capuj[3,4], J. Maire[1], M. Colombano[1,5], P. D. Garcia[1], M. Sledzinska[1], F. Alzina[1], A. Griol[6], A. Martinez[6], C. Sotomayor-Torres[1,7]

[1] *Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona*
Institute of Science and Technology, Campus UAB, Bellaterra, 08193 Barcelona,
Spain
[2] *MIND-IN2UB, Departament d'Electrònica, Facultat de Física, Universitat de Barcelona, Martí i Franquès 1, 08028 Barcelona, Spain*
[3]*Depto. Física, Universidad de la Laguna, La Laguna, Spain*
[4] *Instituto Universitario de Materiales y Nanotecnología, Universidad de La Laguna, 38200 San Cristóbal de La Laguna, Spain.*
[5] *Depto. Física, Universidad Autónoma de Barcelona, Bellaterra, 08193 Barcelona, Spain.*
[6] *Nanophotonics Technology Center, Universitat Politècnica de Valencia, Spain*
[7] *Catalan Institute for Research and Advances Studies ICREA, Barcelona, Spain*

dnavarro@ub.edu

Nonlinear dynamics is a branch of physics that studies systems described by equations more complex than the linear form. Nonlinear systems, such as the weather or neurons, often appear chaotic, unpredictable or counterintuitive, and yet their behaviour is deterministic. In this work we report on the generation and characterization of the nonlinear dynamics of a Si-based optomechanical cavity generated by exploiting nonlinear optical effects typical in silicon resonators and their intercoupling with the mechanical degrees of freedom of the system [1].

For a given wavelength and power in the cavity, the dynamical solution of the system can be a self-sustained oscillation called self-pulsing that modulates light in a coherent way. When a harmonic of the main frequency of the self-pulsing is resonant with a mechanical mode there is a strong amplification of the motion leading to a “phonon lasing” regime (bottom panels of Figure 1)[2] . If the number of photons is large enough, the dynamics of the system became increasingly complex and evolve towards a period-doubling cycle and finally chaos (upper panels of Figure 1). The results of our work could be exploited in many ways but we will discuss their possible implications towards secure communications based on chaos using optomechanical systems.

References

[1] D. Navarro-Urrios et al., Nature Communications, 8, 14965 doi:10.1038/ncomms14965 (2017).

[2] D. Navarro-Urrios et al., Nature Scientific Reports 5, 15733 doi:10.1038/srep15733 (2015).

Figures

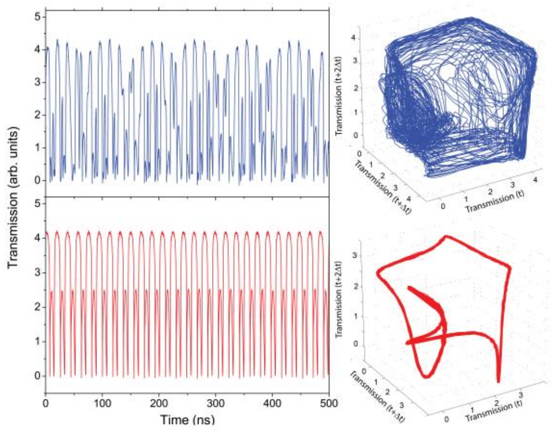

Figure 1: Demonstration of transition between the coherent and chaotic optomechanical regimes. Left: Transmission of the optical signal as a function of time showing a coherent process (lower trace in red) and a chaotic signal (upper trace in blue). Right: Reconstruction of the embedding states in a three-dimensional projection as extracted from the temporal signals of the left panels.