Synchronization, self-oscillation and driven oscillation of a field emission nanowire

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1. Introduction

Synchronization is an ubiquitous phenomenon [1] appearing in various systems such as neural networks, lasers, charge density waves, Josephson junction arrays, heart/breathing systems and population of flashing fireflies, and it is expected to be exploited for the treatment of Parkinson's disease, signal processing or opto-mechanical systems to name a few. Synchronization is only possible in systems demonstrating self-oscillations. Self-oscillating device in nanomechanics have been recently fabricated for optical and electrical systems but synchronization experiments are rather scarce and do not exploit the potentiality of strong non-linearity's in nanomechanics to unveil new phenomena.

2. Experiments and results

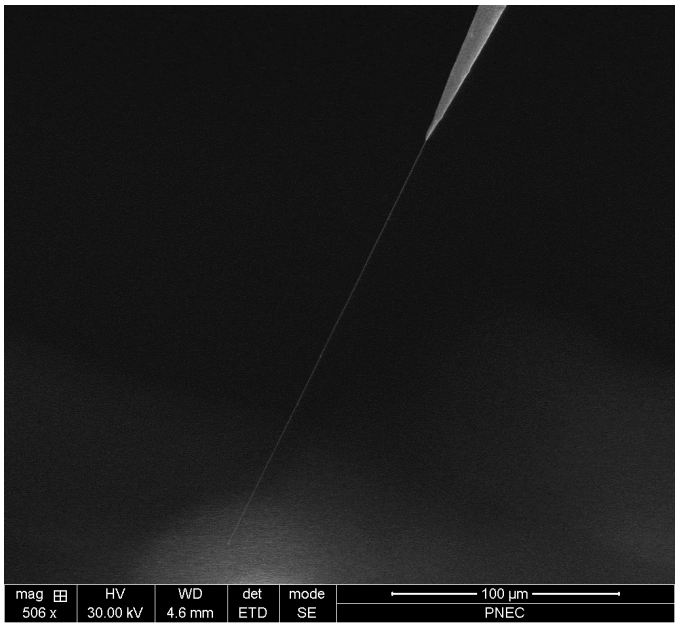

Figure 1: SiC nanowire in a single clamped geometry.

We performed transport measurements with SiC nanowires in a single clamped geometry (Fig. 1) by applying a DC voltage. At the free end of the nanowire electrons can tunnel into vacuum

due to the electric field tip amplification. Above a threshold voltage, this electromechanical nano-object self-oscillates. Applying an additional AC electrostatic excitation locks the self-oscillation natural frequency of the nanowire to the external frequency even for frequencies deviating from each other by roughly 10 %. In the regime of strong driving, unusual behaviors of the phase of the locked self-oscillator are observed showing very distinct features compared to a driven resonator (Fig. 2). Transition from overdamped to damped phase dynamics is clearly demonstrated as well as spontaneous phase modulation motion close to the boundary of the Arnold tongue similar to some form of self-oscillation of the self-oscillator (also called phase trapping).

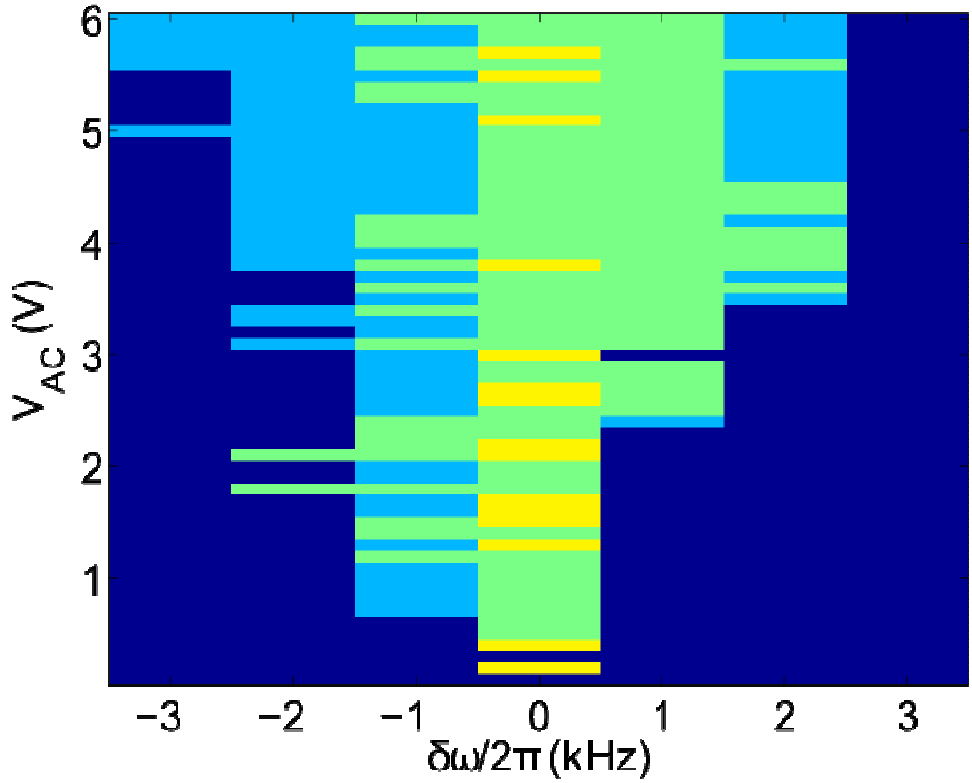

Figure 2: Arnold tongue of a synchronized nanowire with four phase regime: self-oscillation regime (dark blue), phase self-oscillation regime (light blue), phase inertia regime (green) and overdamped phase regime (yellow).

[1] A. Pikovsky, M. Rosenblum, J. Kurths, *Synchronization: A Universal Concept in Nonlinear Sciences* (Cambridge Nonlinear Science Series, 2003)

[2] A. Ayari, P. Vincent, S. Perisanu, M. Choueib, V. Gouttenoire, M. Bechelany, D. Cornu, S. T. Purcell, *Self-Oscillations in Field Emission Nanowire Mechanical Resonators: A Nanometric dc−ac Conversion* Nano Lett. **7**, 2252 (2007)

[3] P. G. Steeneken, K. le Phan, M. J. Goossens, G. E. J. Koops, G. J. A. M. Brom, C. van der Avoort, J. T. M. van Beek, *Piezoresistive heat engine and refrigerator* Nat. Phys. **7** 354 (2011)

[4] D. Grogg, S. Ayoz, A. Ionescu *Self-sustained low power oscillator based on vibrating body field effect transistor* IEEE International Electron Devices Meeting (IEDM) pp.1-4 (2009)

[5] T. Barois, S. Perisanu, P. Vincent, S. T. Purcell and A. Ayari *Frequency modulated self-oscillation and phase inertia in a synchronized nanowire mechanical resonator* New J. Phys. **16** 083009 (2014)