Marie Curie ITN cQOM
Summary of the Scientific Achievements

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Academic / Industrial Institution: LPN-CNRS
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1. Description of research work

The main focus of my PhD work was the study of nonlinear dynamics of a NOEMS platform. The system consisted of suspended photonic crystal membrane (with high reflectivity at normal incidence) driven via interdigitated electrodes. The first part of the PhD work was design, optimization and fabrication of the NOEMS platform. The second part then focused on the study of nonlinear dynamical phenomena with the nanomechanical platform.

2. Goals achieved and/or progress towards them

The first part of the thesis was to optimize and fabricate a suspended photonic crystal membrane- electrode structure. For this purpose, I was required to perform FEM simulations in order to optimize the design, which mainly concentrated on two aspects. Firstly, optimization of the membrane geometry and secondly optimization of the electrode mechanical coupling factor. The later included optimization of the electrode geometry and the membrane electrode separation. The next step was to fabricate the desired structure. This involved several processes, such as: electron beam lithography, dry etching, wet etching, substrate bonding, critical point drying, wire bonding etc., most of which I could perform independently in the clean room. The final fabricated structure is shown in Figure 1.

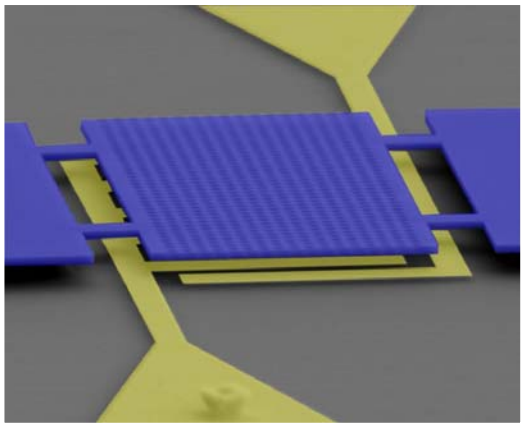

Figure 1 : Suspended photonic crystal nanomechanical membrane over gold interdigitated electrodes

After the fabrication was performed, I performed some experiments concerning the basic properties of the system directly linked with the FEM simulations performed previously. Subsequently, experiments on nonlinear dynamics with this nanomechanical system were investigated. The first experiment with nonlinear dynamics that was performed on this system is called *super harmonic resonance*. In this experiment the nonlinearity of the nanomechanical platform was utilized in order to generate resonant response even when the system was driven far away from resonance. To be precise, the nanomechanical system was driven at the subharmonics of the resonant frequency while being probed at resonance. This gave rise to tongue like response with the excitation voltage, which is known as the *instability tongues.* The instability tongues with superharmonic resonances up to 8th order is shown in Figure 2. Another important result that we obtained which is not shown here is the evolution of the phase rotation across the instability tongue.

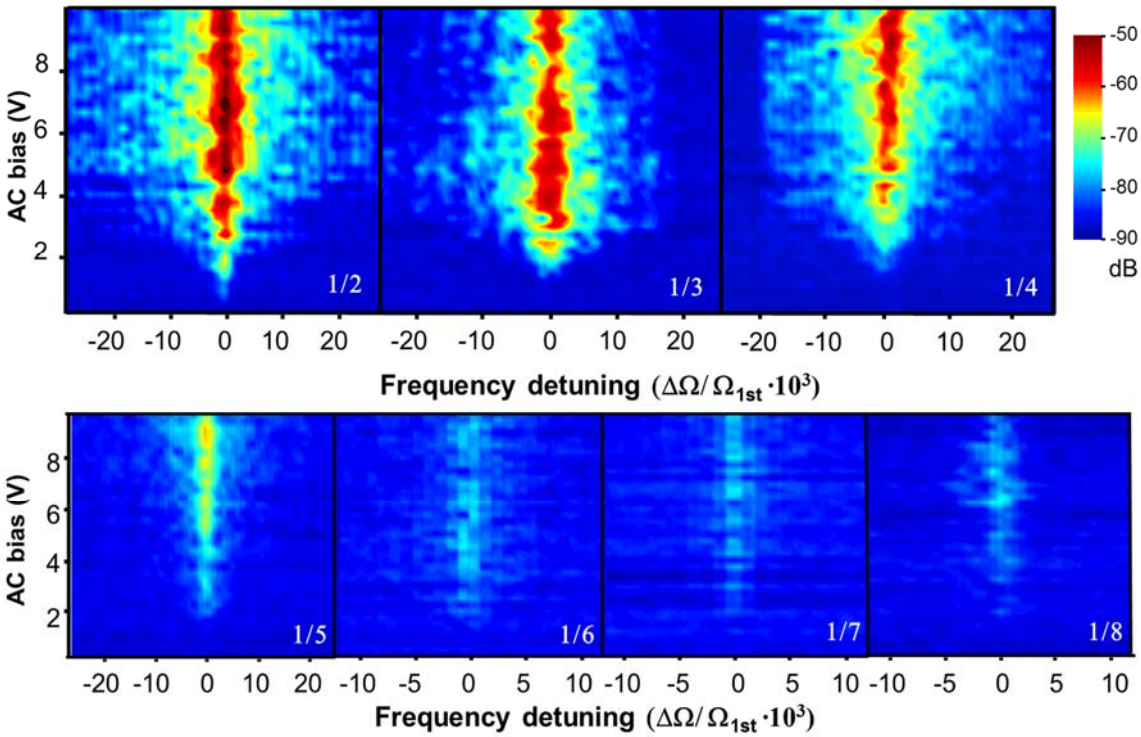

Figure 2: Superharmonic resonances of NOEMS platform for up to 8th order

After we performed these experiments, we switched to experiments on another phenomenon related to nonlinear dynamics. This is known as *stochastic resonance*. The idea of stochastic resonance is amplification of weak signals via noise by using the nonlinearity in the system. We performed experiments with stochastic resonance for amplitude as well as for phase. Although stochastic resonance with amplitude has been demonstrated before, stochastic resonance with phase has been scarce. The phenomenon of stochastic resonance with the response in gain and the state switching in phase space is demonstrated in Figure 3. Phase stochastic resonance along with amplification can be used in applications such as phase encoded communications (for ex. PSK), which are the new standard for communication.

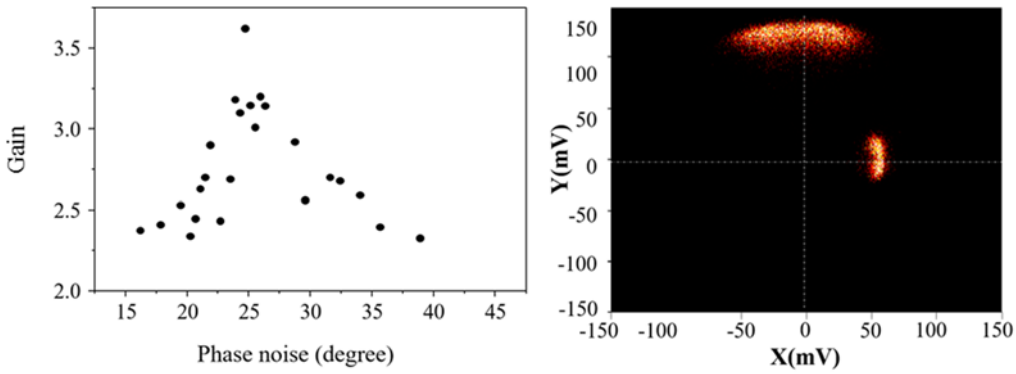

Figure 3: Gain with stochastic resonance in phase and the stochastic resonance in phase space

3. Training received (complementary/soft skills, ITN workshops attended)

ITN workshops:

- Experimental toolbox for cavity optomechanics, Paris (France), 2-4 April 2014.
- Finite element modelling, Lausanne (Switzerland), 21-23 July 2014.
- Diavolezza annual workshops, 1-5 February 2015 and 31 January - February 2016.
- "Taking a Research Idea to a Product", Zurich (Switzerland), 30 November – 1 December 2015.
- "From Photonics Research to the CMOS-fab", Ghent (Belgium), 17-19 May 2016.

Soft skills workshop:

- How to write a scientific paper, 21-24 March 2016.

4. List of conferences attended

- PHONONICS 2015, Paris, France (poster presentation)
- META 15, New York, USA (oral presentation)
- SPIE Photnic west 2016, San Francisco, USA (oral presentation)

5. Publications (with links)

A. Chowdhury, I. Yeo, V. Tsvirkun, F. Raineri, G. Beaudoin, I. Sagnes, R. Raj, I. Robert-Philip and R. Braive. "Superharmonic resonances in a two dimensional non-linear photonic-crystal nano-electro-mechanical oscillator". APL 108, 163102 (2016). http://dx.doi.org/10.1063/1.4947064

6. Career plans after ITN

I plan to defend my thesis in September 2016. I plan to continue in academia with my research focus on optomechanics. At the moment I am contemplating a future postdoc position with another host institution.