Theory of parametric resonance in nanoelectromechanical systems

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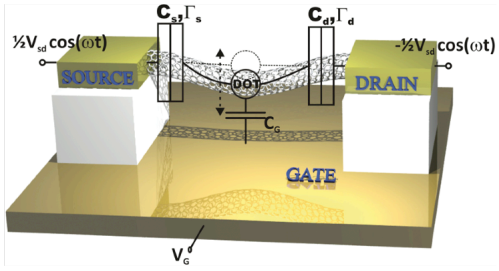
The miniaturization of electronic devices is one of the major technological issues of our century. For instance, the size limit of semiconductor-based transistors seems to be reached soon. There is nowadays a strong fundamental and applied research activity aiming at developing alternative technologies. One of the candidates, proposed by Aviram and Ratner in the seventies, is a single molecule connected to source and drain electrodes. Since then, with the rise of *molecular electronics*, these single-molecule devices attracted a lot of interest, from both, the theoretical and experimental point of view.

Experiments on single-molecule junctions observe many effects from conventional nanostructures such as quantum dots. A prominent example is the Coulomb blockade, which arises due to the large charging energy of nanostructures. Beyond these similarities, single-molecule junctions also bring several new issues into focus.



One prime difference between transport through single molecules as opposed to transport through quantum dots lies in the coupling of the electronic degrees of freedom responsible for transport to few well-defined vibrational modes. We will consider in this *theoretical* PhD thesis a suspended nanoresonator (e.g., a carbon nanotube) connected to source and drain leads, thus forming a *nanoelectromechanical system* (see figure). Here, the influence of the coupling between the electrons and the nanotube vibrational modes on the transport characteristics will be investigated. In particular, we will analyze the role that can play the parametric amplification of the fundamental flexural mode of the tube (which can be generated by a periodic modulation of its vibrational frequency, as recently realized in experiments [1]) on the transport properties of the nanotube.

The theoretical tools for investigating this topic are the basic concepts of quantum transport through mesoscopic systems. We will be primarily interested in the current-voltage characteristics and the noise of such a device. Both analytical and numerical calculations using an effective Langevin approach [2] will be of help to tackle this challenging problem. We will also investigate the role of electronic correlations (that can be crucial at the nanoscale) on the transport properties, using the Density Matrix Renormalization Group together with the embedding method developped in our team [3] that will be extended in order to take into account vibrational degrees of freedom.

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