I. INTRODUCTION

Nanoscopic physics has been a subject of increasing experimental and theoretical interest for its potential applications in nanoelectromechanical systems (NEMS)[1–3]. The physical properties of these devices are of crucial importance in improving our understanding of the fundamental science in this area including many-body phenomena[4]. One of the most striking paradigms exhibiting many body effects in mesoscopic science is quantum transport through single electronic levels in quantum dots and single molecules[5–8] coupled to external leads. Realizations of these systems have been obtained using semiconductor beams coupled to single electron transistors (SET's) and superconducting single electron transistors (SSET's)[9,10], carbon nanotubes[11] and, most recently, suspended graphene sheets[12]. Such systems can be used as a direct measure of small displacements, forces and mass in the quantum regime. The quantum transport properties of these systems require extremely sensitive measurement that can be achieved by using SET's, or a resonant tunnel junction, and SSET's. In this context, NEMS are not only interesting devices studied for ultrasensitive transducers but also because they are expected to exhibit several exclusive features of transport phenomena such as avalanche-like transport and shuttling instability[13,14]. The nanomechanical properties of a resonant tunnel junction coupled to an oscillator[15] or a SET[16,17] coupled to an oscillator are currently playing a vital role in enhancing the understanding of NEMS.

The nanomechanical oscillator coupled to a resonant tunnel junction or SET is a close analogue of a molecule being used as a sensor whose sensitivity has reached the quantum limit[1–3,9,18]. The signature of quantum states has been predicted for the nanomechanical oscillator coupled to the SET's[9] and SSET's[10,19]. In these experiments, it has been confirmed that the nanomechanical oscillator is strongly affected by the electron transport in the circumstances where we are also trying to explore the quantum regime of NEMS. In this system, electrons tunnel from one of the leads to the isolated conductor and then to the other lead. Phonon assisted tunneling of non–resonant systems has mostly been shown by experiments on inelastic tunneling spectroscopy (ITS). With the advancement of modern technology, as compared to ITS, scanning tunneling spectroscopy (STS) and scanning tunneling microscopy (STM) have proved more valuable tools for the investigation and characterization of molecular systems[20] in the conduction regime. In STS experiments, significant signatures of the strong electron-phonon interaction have been observed[21,22] beyond the established