From Classical Mechanics to Quantum-Electro-Mechanics

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Classical Mechanics is what lies at the beginning of the physics curriculum as everyone will recall from numerous textbook questions. The transition to quantum mechanics is traditionally treated by looking into atomic and molecular physics. However, semiconductor processing techniques by now allow to build systems with a mechanical degree of freedom on the micron and nanometer scale. Hence, one can envision to machine systems for studying quantum electro mechanics (QEM).

In terms of applications such nano-electromechanical systems (NEMS) as compared to MEMS on the micron-scale are also found in sensor and communication components. Especially, in communication applications they are valuable additions as switching, filter, and mixer elements. The mechanical resonance frequencies for NEMS are now of the order of 1 – 2 GHz, which makes NEMS-circuits compatible with CMOS. In terms of sensor applications, I want to focus on mass sensing: NEMS implies not only microwave operating frequencies, but in addition NEMS possess extremely small masses. This inherent high sensitivity for mass sensing is of crucial importance for a number of areas such as the ever expanding field of proteomics.

Finally, I will stress the importance of quantum effects analyzed with NEMS. Prominent examples being the interaction of single electrons and single phonon modes and the observation of the Casimir force in such mechanical resonators. Similarly, the mechanical degree of freedom on the nanometer scale can also be used to shuttle single electrons at radio frequencies in a non-stochastic manner. As an outlook, I will present first results on tubular shaped NEMS with an integrated low-dimensional electron gas. Such a topology can induce a geometrical confinement potential for electrons, which can be added to the electro-magnetically induced confinement.