Mesoscopic phenomena in the electromechanics of suspended nanowires

GUSTAV SONNE

GÖTEBORGS UNIVERSITET

Akademisk avhandling som för avläggande av filosofie doktorsexamen vid Göteborgs universitet försvaras vid offentlig disputation den 15:e april 2011, klockan 10.00 i Kollektorn, Institutionen för mikroteknologi och nanovetenskap (Chalmers), Kemivägen 9, Göteborg. Uppsatsen presenteras på engelska.

Fakultetsopponent:	Professor Andrew Armour School of Physics and Astronomy University of Nottingham, United Kingdom
Huvudhandledare:	Docent Leonid Gorelik Institutionen för teknisk fysik Chalmers tekniska högskola
Examinator:	Professor Mats Jonson Institutionen för fysik Göteborgs universitet

Avhandlingen finns tillgänglig vid

Institutionen för fysik
Göteborgs universitet
412 96 Göteborg
Telefon +46 (0)31 786 0000

Mesoscopic phenomena in the electromechanics of suspended nanowires
GUSTAV SONNE
Condensed Matter Theory
Department of Physics
University of Gothenburg
ISBN: 978-91-628-8244-0

ABSTRACT

Over the last two decades nanotechnology has been a very active field of scientific research, both from fundamental perspectives as well as for applications in technology and consumer goods. In this thesis, theoretical work on quantum mechanical effects on charge transport in nanoelectromechanical systems is presented. In particular, the effects of electron-vibron interactions in suspended nanowire structures are analysed and discussed.

The thesis is structured around the appended scientific publications by the author. Also included is an introductory section where the underlying theory and motivation is presented. This introduction forms the basis on which the subsequent material and appended papers is based.

The work presented in the appended papers considers systems comprising suspended oscillating nanowires, primarily in the form of carbon nanotubes. Central to these studies is the interaction between the charge transport and the mechanical motion of the nanowires. For the systems analysed in this thesis, these interactions are mediated through transverse magnetic fields, the effect of which is studied in various system setups. In particular, three topics of mesoscopic phenomena are presented; i) a temperature-independent current deficit due to interference effects between different electronic tunnelling paths over the nanowire-junction, ii) pumping of the mechanical vibrations in a low transparency superconducting junction, and iii) cooling of the mechanical vibrations in both current- and voltage-biased superconducting junctions.

The outcome of the presented work is a number of interesting physical predictions for the electromechanics of suspended nanowires. These results are shown to be experimentally observable in systems with high mechanical resonance frequencies and if sufficiently strong electromechanical coupling can be achieved. Once these conditions are fulfilled, the predicted results are of interest both from a fundamental perspective in that they probe the underlying quantum nature of the systems, but also for sensing applications where quantum limited resolution could be experimentally achievable.

Keywords: Nanoelectromechanical systems, ground-state cooling, superconducting weak links, carbon nanotubes, non-linear resonance,