



# Interacting Electrons in Reduced Dimensions

Edited by  
**Dionys Baeriswyl** and  
**David K. Campbell**

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# Interacting Electrons In Reduced Dimensions

**Stig Lundqvist, Nils Robert Nilsson**



## **Interacting Electrons In Reduced Dimensions:**

**Interacting Electrons in Reduced Dimensions** Dionys Baeriswyl, David K. Campbell, 2012-12-06 As its name suggests the 1988 workshop on Interacting Electrons in Reduced Dimensions the wide variety of physical effects that are associated with possibly systems focused on strongly correlated electrons interacting in quasi one and quasi two dimensional materials Among the phenomena discussed were superconductivity magnetic ordering the metal insulator transition localization the fractional Quantum Hall effect QHE Peierls and spin Peierls transitions conductance fluctuations and sliding charge density CDW and spin density SDW waves That these effects appear most pronounced in systems of reduced dimensionality was amply demonstrated at the meeting Indeed when concrete illustrations were presented they typically involved chain like materials such as conjugated polymers inorganic CDW systems and organic conductors or layered materials such as high temperature copper oxide superconductors certain of the organic superconductors and the QHE samples or devices where the electrons are confined to a restricted region of sample e.g. the depletion layer of a MOSFET To enable this broad subject to be covered in thirty five lectures and about half as many posters the workshop was deliberately focused on theoretical models for these phenomena and on methods for describing as faithfully as possible the true behavior of these models This latter emphasis was especially important since the inherently many body nature of problems involving interacting electrons renders conventional effective single particle mean field methods e.g. Hartree Fock or the local density approximation in density functional theory highly suspect Again this is particularly true in reduced dimensions where strong quantum fluctuations can invalidate mean field results

**Optical Phenomena in Semiconductor Structures of Reduced Dimensions** D.J. Lockwood, Aron Pinczuk, 2012-12-06 Remarkable advances in semiconductor growth and processing technologies continue to have a profound impact on condensed matter physics and to stimulate the invention of novel optoelectronic effects Intensive research on the behaviors of free carriers has been carried out in the two dimensional systems of semiconductor heterostructures and in the one and zero dimensional systems of nanostructures created by the state of the art fabrication methods These studies have uncovered unexpected quantum mechanical correlations that arise because of the combined effects of strong electron-electron interactions and wave function confinement associated with reduced dimensionality The investigations of these phenomena are currently at the frontiers of condensed matter physics They include areas like the fractional quantum Hall effect the dynamics of electrons on an ultra short femtosecond time scale electron behavior in quantum wires and dots and studies of electron tunneling phenomena in ultra small semiconductor structures Optical techniques have made important contributions to these fields in recent years but there has been no coherent review of this work until now The book provides an overview of these recent developments that will be of interest to semiconductor materials scientists in university government and industrial laboratories

Condensed Systems of Low Dimensionality J.L. Beeby, P.K. Bhattacharya, P.Ch. Gravelle, F. Koch, D.J. Lockwood, 2012-12-06 The NATO Special Programme Panel on

Condensed Systems of Low Dimensionality began its work in 1985 at a time of considerable activity in the field. The Panel has since funded many Advanced Research Workshops, Advanced Study Institutes, Cooperative Research Grants and Research Visits across the breadth of its remit which stretches from self-organizing organic molecules to semiconductor structures having two, one and zero dimensions. The funded activities, especially the workshops, have allowed researchers from within NATO countries to exchange ideas and work together at a period of development of the field when such interactions are most valuable. Such timely support has undoubtedly assisted the development of national programs particularly in the countries of the alliance wishing to strengthen their science base. A closing Workshop to mark the end of the Panel's activities was organized in Marmaris, Turkey from April 23-27, 1990 with the same title as the Panel: Condensed systems of Low Dimensionality. This volume contains papers presented at that meeting which sought to bring together chemists, physicists and engineers from across the spectrum of the Panel's activities to discuss topics of current interest in their special fields and to exchange ideas about the effects of low dimensionality. As the following pages show, this is a topic of extraordinary interest and challenge which produces entirely new scientific phenomena and at the same time offers the possibility of novel technological applications.

*Lower-Dimensional Systems and Molecular Electronics* Robert M. Metzger, Peter R. Day, George C. Papavassiliou, 2013-11-11. This volume represents the written account of the NATO Advanced Study Institute Lower Dimensional Systems and Molecular Electronics held at Hotel Spetses, Spetses Island, Greece from 12 June to 23 June 1989. The goal of the Institute was to demonstrate the breadth of chemical and physical knowledge that has been acquired in the last 20 years in inorganic and organic crystals, polymers and thin films which exhibit phenomena of reduced dimensionality. The interest in these systems started in the late 1960s with lower dimensional inorganic conductors, in the early 1970s with quasi one-dimensional crystalline organic conductors which by 1979 led to the first organic superconductors and in 1977 to the first conducting polymers. The study of monolayer films, Langmuir-Blodgett films, had progressed since the 1930s but reached a great upsurge in the early 1980s. The pursuit of non-linear optical phenomena became increasingly popular in the early 1980s as the attention turned from inorganic crystals to organic films and polymers. And in the last few years the term molecular electronics has gained ever increasing acceptance although it is used in several contexts. We now have organic superconductors with critical temperatures in excess of 10 K, conducting polymers that are soluble and processable and used commercially, we have films of a few monolayers that have high in-plane electrical conductivity and polymers that show great promise in photonics; we even have a few devices that function almost at the molecular level.

**Proceedings of the Symposium on Electroresponsive Molecular and Polymeric Systems, Brookhaven National Laboratory** Terje A. Skotheim, 1990. *Strongly Correlated Electron Systems - Proceedings Of The Anniversary Adriatico Research Conference And Workshop* G. Baskaran, A. E. Ruckenstein, Lu Yu, Erio Tosatti, 1990-01-01.

**Science and Engineering of One- and Zero-Dimensional Semiconductors** Steven P. Beaumont, Clivia M. Sotomayor

Torres,2012-12-06 This volume comprises the proceedings of the NATO Advanced Research Workshop on the Science and Engineering of 1 and 0 dimensional semiconductors held at the University of Cadiz from 29th March to 1st April 1989 under the auspices of the NATO International Scientific Exchange Program There is a wealth of scientific activity on the properties of two dimensional semiconductors arising largely from the ease with which such structures can now be grown by precision epitaxy techniques or created by inversion at the silicon silicon dioxide interface Only recently however has there burgeoned an interest in the properties of structures in which carriers are further confined with only one or in the extreme zero degrees of freedom This workshop was one of the first meetings to concentrate almost exclusively on this subject that the attendance of some forty researchers only represented the community of researchers in the field testifies to its rapid expansion which has arisen from the increasing availability of technologies for fabricating structures with small enough sub  $\mu\text{m}$  dimensions Part I of this volume is a short section on important topics in nanofabrication It should not be assumed from the brevity of this section that there is little new to be said on this issue rather that to have done justice to it would have diverted attention from the main purpose of the meeting which was to highlight experimental and theoretical research on the structures themselves

**Electron-phonon Interactions in Low-dimensional Structures** Lawrence John Challis,2003 The study of electrons and holes confined to two one and even zero dimensions has uncovered a rich variety of new physics and applications This book describes the interaction between these confined carriers and the optic and acoustic phonons within and around the confined regions Phonons provide the principal channel of energy transfer between the carriers and their surroundings and also the main restriction to their room temperature mobility But they have many other roles they provide for example an essential feature of the operation of the quantum cascade laser Since their momenta at relevant energies are well matched to those of electrons they can also be used to probe electronic properties such as the confinement width of 2D electron gases and the dispersion curve of quasiparticles in the fractional quantum Hall effect The book describes both the physics of the electron phonon interaction in the different confined systems and the experimental and theoretical techniques that have been used in its investigation The experimental methods include optical and transport techniques as well as techniques in which phonons are used as the experimental probe The aim of the book is to provide an up to date review of the physics and its significance in device performance It is also written to be explanatory and accessible to graduate students and others new to the field

**Low-Dimensional Systems** Tobias Brandes,2008-01-11 Experimental progress over the past few years has made it possible to test a number of fundamental physical concepts related to the motion of electrons in low dimensions The production and experimental control of novel structures with typical sizes in the sub micrometer regime has now become possible In particular semiconductors are widely used in order to confine the motion of electrons in two dimensional heterostructures The quantum Hall effect was one of the first highlights of the new physics that is revealed by this confinement In a further step of the technological development in semiconductor heterostructures other artificial devices such

as quasi one dimensional quantum wires and quantum dots artificial atoms have also been produced These structures again differ very markedly from three and two dimensional systems especially in relation to the transport of electrons and the interaction with light Although the technological advances and the experimental skills connected with these new structures are progressing extremely fast our theoretical understanding of the physical effects such as the quantum Hall effect is still at a very rudimentary level In low dimensional structures the interaction of electrons with one another and with other degrees of freedoms such as lattice vibrations or light gives rise to new phenomena that are very different from those familiar in the bulk material The theoretical formulation of the electronic transport properties of small devices may be considered well established provided interaction processes are neglected Condensed Matter Field Theory Alexander Altland, Ben D.

Simons, 2010-03-11 This primer is aimed at elevating graduate students of condensed matter theory to a level where they can engage in independent research Topics covered include second quantisation path and functional field integration mean field theory and collective phenomena Strongly Correlated Fermions and Bosons in Low-Dimensional Disordered Systems Igor V. Lerner, Boris L. Altshuler, Vladimir I. Fal'ko, Thierry Giamarchi, 2012-12-06 The physics of strongly correlated fermions and bosons in a disordered environment and confined geometries is at the focus of intense experimental and theoretical research efforts Advances in material technology and in low temperature techniques during the last few years led to the discoveries of new physical phenomena of atomic gases and a possible metal phenomena including Bose condensation insulator transition in two dimensional high mobility electron structures Situations where the electronic system is so dominated by interactions that the old concepts of a Fermi liquid do not necessarily make a good starting point are now routinely achieved This is particularly true in the theory of low dimensional systems such as carbon nanotubes or in two dimensional electron gases in high mobility devices where the electrons can form a variety of new structures In many of these systems disorder is an unavoidable complication and lead to a host of rich physical phenomena This has pushed the forefront of fundamental research in condensed matter towards the edge where the interplay between many body correlations and quantum interference enhanced by disorder has become the key to the understanding of novel phenomena **Inelastic Light Scattering of**

**Semiconductor Nanostructures** Christian Schüller, 2006-09-14 The field of semiconductor nanostructures is of enormous and still growing research interest On one hand they are already realized in mass products such as high electron mobility field effect transistors and quantum well lasers On the other hand they allow in specially tailored systems the investigation of fundamental properties such as many particle interactions of electrons in reduced dimensions This book bridges the gap between general semiconductor textbooks and research articles *Aspects topologiques de la physique en basse dimension. Topological aspects of low dimensional systems* A. Comtet, T. Jolicoeur, S. Ouvry, F. David, 2000-01-20 Session LXIX 7 31 July 1998 Strong Interactions in Low Dimensions D. Baeriswyl, L. Degiorgi, 2007-09-29 This book provides an attempt to convey the colorful facets of condensed matter systems with reduced dimensionality Some of the specific features predicted

for interacting one dimensional electron systems such as charge and spin density waves have been observed in many quasi one dimensional materials The two dimensional world is even richer besides d wave superconductivity and the Quantum Hall Effect perhaps the most spectacular phases explored during the last two decades many collective charge and spin states have captured the interest of researchers such as charge stripes or spontaneously generated circulating currents Recent years have witnessed important progress in material preparation measurement techniques and theoretical methods Today larger and better samples higher flux for neutron beams advanced light sources better resolution in electron spectroscopy new computational algorithms and the development of field theoretical approaches allow an in depth analysis of the complex many body behaviour of low dimensional materials The epoch when simple mean field arguments were sufficient for describing the gross features observed experimentally is definitely over The Editors aim is to thoroughly explain a number of selected topics the application of dynamical probes such as neutron scattering optical absorption and photoemission as well as transport studies both electrical and thermal Some of the more theoretical chapters are directly relevant for experiments such as optical spectroscopy transport in one dimensional models and the phenomenology of charge inhomogeneities in layered materials while others discuss more general topics and methods for example the concept of a Luttinger liquid and bosonization or duality transformations both promising tools for treating strongly interacting many body systems

**Finite Size Effects in Correlated Electron Models** Andrei A. Zvyagin, 2005 The book presents exact results for one dimensional models including quantum spin models of strongly correlated electrons in a comprehensive and concise manner It incorporates important results related to magnetic and hybridization impurities in electron hosts and contains exact original results for disordered ensembles of impurities in interacting systems These models describe a number of real low dimensional electron systems that are widely used in nanophysics and microelectronics An important method of modern theoretical and mathematical physics the Bethe s Ansatz BA is introduced to readers This book presents different forms of the BA for periodic and open quantum chains Other forms dealt with are the co ordinate BA thermodynamic BA nested BA algebraic BA and thermal BA The book also contains a compact description of other theoretical methods such as scaling conformal field theory Abelian and non Abelian bosonizations The book is suitable for use as a textbook by graduate students in non perturbative methods of low dimensional quantum many body theory It will also be a useful source of reference for qualified physicists as well as non experts in low dimensional physics as it explores material necessary for further studies in the fields of exactly solvable quantum models and low dimensional correlated electron systems

**Introducing Molecular Electronics** Gianaurelio Cuniberti, Giorgos Fagas, Klaus Richter, 2006-05-21 Klaus von Klitzing Max Planck Institut fur Festk orperforschung Heisenbergstra e 1 70569 Stuttgart Germany Already many Cassandras have prematurely announced the end of the silicon roadmap and yet conventional semiconductor based transistors have been continuously shrinking at a pace which has brought us to nowadays cheap and powerful microelectronics However it is clear that the traditional scaling laws

cannot be applied if unwanted tunnel phenomena or ballistic transport dominate the device properties. It is generally expected that a combination of silicon CMOS devices with molecular structure will dominate the field of nanoelectronics in 20 years. The visionary ideas of atomic or molecular scale electronics already date back thirty years but only recently advanced nanotechnology including e.g. scanning tunneling methods and mechanically controllable break junctions have enabled to make distinct progress in this direction. On the level of fundamental research, state-of-the-art techniques allow to manipulate image and probe charge transport through uni-molecular systems in an increasingly controlled way. Hence molecular electronics is reaching a stage of trustable and reproducible experiments. This has led to a variety of physical and chemical phenomena recently observed for charge currents flowing through molecular junctions posing new challenges to theory. As a result, a still increasing number of open questions determines the future agenda in this field.

**Physics Of Low-dimensional Systems - Proceedings Of Nobel Symposium 73** Stig Lundqvist, Nils Robert Nilsson, 1989-07-01. List of Contributors: P. W. Anderson, S. Tanaka, C. W. Chu, Y. H. Kim, T. V. Ramakrishnan, G. Wendin, G. Baskaran, H. Fukuyama, Y. Hasegawa, A. Zawadowski, A. A. Abrikosov, A. I. Buzdin, V. L. Ginzburg, S. Barisic, I. Batistic, E. J. Mele, L. Dzyaloshinskii, L. A. Falkovsky, J. R. Schrieffer, D. J. Scalapino, A. I. Larkin, K. W. Becker, P. Fulde, S. A. Trugman, F. C. Zhang, K. A. Chao, G. Z. Wei, D. J. Rome et al., J. Bardeen, M. Sinclair, S. M. Girvin, D. P. Arovas, P. B. Wiegmann and others.

*Low-Dimensional Conductors and Superconductors* D. Jerome, L. G. Caron, 2013-12-14. Research activities in low dimensional conductors have shown a rapid growth since 1972 and have led to the discovery of new and remarkable physical properties unique to both molecular and inorganic conductors exhibiting one dimensional transport behaviour. This NATO Institute was a continuation of a series of NATO Advanced Study Institutes or Workshops which took place at regular intervals till 1979. This is the first time however that charge density wave transport and electronic properties of low dimensional organic conductors are treated on an equal footing. The program of the Institute was framed by tutorial lectures in the theories and experiments of low dimensional conductors. The bulk of the course covered two series of low dimensional materials with their respective properties: 1. The 1D inorganic conductors exhibiting the phenomena of sliding charge density waves, narrow band noise, memory effects etc. 2. Low dimensional crystallized organic conductors giving rise to various possibilities of ground states, spin-Peierls, spin density wave, Peierls superconductivity and magnetic field induced spin density wave etc. Since it has been established from the beginning that this Institute was to be devoted essentially to the Physics of Low Dimensional Conductors, only one main course summarized the progress in chemistry and material preparation.

Dissipative Quantum Mechanics of Nanostructures Andrei D. Zaikin, Dmitry Golubev, 2019-05-24. Continuing miniaturization of electronic devices together with the quickly growing number of nanotechnological applications demands a profound understanding of the underlying physics. Most of the fundamental problems of modern condensed matter physics involve various aspects of quantum transport and fluctuation phenomena at the nanoscale. In nanostructures, electrons are usually confined to a limited volume and interact with each other and lattice ions simultaneously suffering multiple scattering.



events on impurities barriers surface imperfections and other defects Electron interaction with other degrees of freedom generally yields two major consequences quantum dissipation and quantum decoherence In other words electrons can lose their energy and ability for quantum interference even at very low temperatures These two different but related processes are at the heart of all quantum phenomena discussed in this book This book presents copious details to facilitate the understanding of the basic physics behind a result and the learning to technically reproduce the result without delving into extra literature The book subtly balances the description of theoretical methods and techniques and the display of the rich landscape of the physical phenomena that can be accessed by these methods It is useful for a broad readership ranging from master s and PhD students to postdocs and senior researchers

**Energy Research Abstracts** ,1989

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