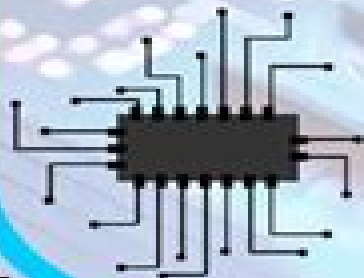


Quantum transport in nanoscale systems

- Quantum transport in nanoscale systems explores how electrons move through materials at the atomic scale, where quantum effects become significant
- This movement is influenced by quantum mechanics, not classical laws, leading to unique properties like superconductivity
- The phenomena underpin revolutionary technologies, including quantum computing and nanoelectronics
- Understanding and harnessing quantum transport is vital for developing next-generation devices

Practical example: Electronics

- Quantum transport in nanoscale systems is fundamental to modern electronics, impacting how devices operate at microscopic levels
- This phenomenon involves the behavior of electrons in materials that are only a few atoms in size
- Understanding quantum transport allows engineers to design more efficient, faster semiconductors used in everything from smartphones to computers
- As electronic components shrink, mastering quantum transport is key to pushing the boundaries of what our devices can do



Quantum Transport

Kenji Hirose, Nobuhiko Kobayashi



Quantum Transport:

Quantum Transport in Submicron Devices Wim Magnus, Wim Schoenmaker, 2002-06-12 The aim of this book is to resolve the problem of electron and hole transport with a coherent and consistent theory that is relevant to the understanding of transport phenomena in submicron devices Along the road readers encounter landmarks in theoretical physics as the authors guide them through the strong and weak aspects of various hypotheses

Quantum Transport and Dissipation Thomas Dittrich, 1998-03-04 The increasing emphasis and importance of mesoscopic systems for tomorrow's high tech electronics industry as well as a growing research interest in the subject has given rise to the need for a modern introductory text at the graduate level This book aims to provide the necessary theory and tools to carry out research into the various aspects of the subject It starts with a chapter on the theory of quantum transport giving a survey of the basic theory used in transport phenomena including scattering linear response theory weak localization conductance fluctuations and the Landauer-Büttiker formalism Various aspects of chaos in quantum systems as well as dissipative quantum systems are discussed Other topics of importance such as single electron tunneling driven bistable systems quantized transport and electron liquids are also covered in detail Graduate students as well as newcomers to this exciting and expanding field will find this work useful to adopt the necessary theory and overview required to go deeper into the original literature and to carry out research

Quantum Kinetics in Transport and Optics of Semiconductors Hartmut Haug, Antti-Pekka Jauho, 2007-12-10 Nanoscale miniaturization and femtosecond laser pulse spectroscopy require a quantum mechanical description of the carrier kinetics that goes beyond the conventional Boltzmann theory On these extremely short length and time scales the electrons behave as do partially coherent waves This monograph deals with quantum kinetics for transport in low dimensional microstructures and for ultra short laser pulse spectroscopy The nonequilibrium Green function theory is described and used for the derivation of the quantum kinetic equations Numerical methods for the solution of the retarded quantum kinetic equations are discussed and results are presented for high field transport and for mesoscopic transport phenomena Quantum beats polarization decay and non Markovian behaviour are treated for femtosecond spectroscopy on a microscopic basis Since the publishing of the first edition in 1996 the nonequilibrium Green function technique has been applied to a large number of new research topics and the revised edition introduces the reader to many of these areas such as molecular electronics noise calculations build up of screening and polaron correlations and non Markovian relaxation among others Connection to recent experiments is made and it is emphasized how the quantum kinetic theory is essential in their interpretation

Quantum Transport Theory Jorgen Rammer, 2004-09-03 Quantum Transport Theory is a comprehensive account of recent achievements in the understanding of disordered conductors Chapters cover the density matrix description of nonequilibrium statistical mechanics

An Introduction to Quantum Transport in Semiconductors David K. Ferry, 2017-12-14 Throughout their college career most engineering students have done problems and studies that are

basically situated in the classical world Some may have taken quantum mechanics as their chosen field of study This book moves beyond the basics to highlight the full quantum mechanical nature of the transport of carriers through nanoelectronic structures The book is unique in that addresses quantum transport only in the materials that are of interest to microelectronics semiconductors with their variable densities and effective masses The author develops Green's functions starting from equilibrium Green's functions and going through modern time dependent approaches to non equilibrium Green's functions introduces relativistic bands for graphene and topological insulators and discusses the quantum transport changes that these bands induce and discusses applications such as weak localization and phase breaking processes resonant tunneling diodes single electron tunneling and entanglement Furthermore he also explains modern ensemble Monte Carlo approaches to simulation of various approaches to quantum transport and the hydrodynamic approaches to quantum transport All in all the book describes all approaches to quantum transport in semiconductors thus becoming an essential textbook for advanced graduate students in electrical engineering or physics

Quantum Transport Supriyo Datta, 2005-06-16 This book presents the conceptual framework underlying the atomistic theory of matter emphasizing those aspects that relate to current flow This includes some of the most advanced concepts of non equilibrium quantum statistical mechanics No prior acquaintance with quantum mechanics is assumed Chapter 1 provides a description of quantum transport in elementary terms accessible to a beginner The book then works its way from hydrogen to nanostructures with extensive coverage of current flow The final chapter summarizes the equations for quantum transport with illustrative examples showing how conductors evolve from the atomic to the ohmic regime as they get larger Many numerical examples are used to provide concrete illustrations and the corresponding Matlab codes can be downloaded from the web Videostreamed lectures keyed to specific sections of the book are also available through the web This book is primarily aimed at senior and graduate students

Quantum Transport Calculations for Nanosystems Kenji Hirose, Nobuhiko Kobayashi, 2014-04-11 As electric devices become smaller and smaller transport simulations based on the quantum mechanics become more and more important There are currently numerous textbooks on the basic concepts of quantum transport but few present calculation methods in detail This book provides various quantum transport simulation methods and shows applications

Quantum Transport in Semiconductors David K. Ferry, Carlo Jacoboni, 2013-06-29 The majority of the chapters in this volume represent a series of lectures that were given at a workshop on quantum transport in ultrasmall electron devices held at San Miniato Italy in March 1987 These have of course been extended and updated during the period that has elapsed since the workshop was held and have been supplemented with additional chapters devoted to the tunneling process in semiconductor quantum well structures The aim of this work is to review and present the current understanding in nonequilibrium quantum transport appropriate to semiconductors Generally the field of interest can be categorized as that appropriate to inhomogeneous transport in strong applied fields These fields are most likely to be strongly varying in

both space and time Most of the literature on quantum transport in semiconductors or in metallic systems for that matter is restricted to the equilibrium approach in which spectral densities are maintained as semiclassical energy conserving delta functions or perhaps incorporating some form of collision broadening through a Lorentzian shape and the distribution functions are kept in the equilibrium Fermi Dirac form The most familiar field of nonequilibrium transport at least for the semiconductor world is that of hot carriers in semiconductors

Quantum Transport in Ultrasmall Devices

David K. Ferry, Harold L. Grubin, Carlo Jacoboni, A.-P. Jauho, 2012-12-06 The operation of semiconductor devices depends upon the use of electrical potential barriers such as gate depletion in controlling the carrier densities electrons and holes and their transport Although a successful device design is quite complicated and involves many aspects the device engineering is mostly to devise a best device design by defining optimal device structures and manipulating impurity profiles to obtain optimal control of the carrier flow through the device This becomes increasingly difficult as the device scale becomes smaller and smaller Since the introduction of integrated circuits the number of individual transistors on a single chip has doubled approximately every three years As the number of devices has grown the critical dimension of the smallest feature such as a gate length which is related to the transport length defining the channel has consequently declined The reduction of this design rule proceeds approximately by a factor of 1.4 each generation which means we will be using 0.1015 μm rules for the 4 Gb chips a decade from now If we continue this extrapolation current technology will require 30 nm design rules and a cell 3.2 size

Theory of Quantum Transport at Nanoscale Dmitry Ryndyk, 2015-12-08 This book is an introduction to a rapidly developing field of modern theoretical physics the theory of quantum transport at nanoscale The theoretical methods considered in the book are in the basis of our understanding of charge spin and heat transport in nanostructures and nanostructured materials and are widely used in nanoelectronics molecular electronics spin dependent electronics spintronics and bio electronics The book is based on lectures for graduate and post graduate students at the University of Regensburg and the Technische Universität Dresden TU Dresden The first part is devoted to the basic concepts of quantum transport Landauer Bttiker method and matrix Green function formalism for coherent transport Tunneling Transfer Hamiltonian and master equation methods for tunneling Coulomb blockade vibrons and polarons The results in this part are obtained as possible without sophisticated techniques such as nonequilibrium Green functions which are considered in detail in the second part A general introduction into the nonequilibrium Green function theory is given The approach based on the equation of motion technique as well as more sophisticated one based on the Dyson Keldysh diagrammatic technique are presented The main attention is paid to the theoretical methods able to describe the nonequilibrium at finite voltage electron transport through interacting nanosystems specifically the correlation effects due to electron electron and electron vibron interactions

Nonequilibrium Quantum Transport Physics In Nanosystems: Foundation Of Computational Nonequilibrium Physics In Nanoscience And Nanotechnology Felix A Buot, 2009-08-05 This book presents the first comprehensive treatment

of discrete phase space quantum mechanics and the lattice Weyl Wigner formulation of energy band dynamics by the originator of these theoretical techniques The author's quantum superfield theoretical formulation of nonequilibrium quantum physics is given in real time without the awkward use of artificial time contour employed in previous formulations These two main quantum theoretical techniques combine to yield general including quasiparticle pairing dynamics and exact quantum transport equations in phase space appropriate for nanodevices The derivation of transport formulas in mesoscopic physics from the general quantum transport equations is also treated Pioneering nanodevices are discussed in the light of the quantum transport physics equations and an in depth treatment of the physics of resonant tunneling devices is given Operator Hilbert space methods and quantum tomography are discussed Discrete phase space quantum mechanics on finite fields is treated for completeness and by virtue of its relevance to quantum computing The phenomenological treatment of evolution superoperator and measurements is given to help clarify the general quantum transport theory Quantum computing and information theory is covered to demonstrate the foundational aspects of discrete quantum dynamics particularly in deriving a complete set of multiparticle entangled basis states

Quantum Transport Nanostructures

Molechb LAMBERT,2021-03-23 This reference text presents a conceptual framework for understanding room temperature electron and phonon transport through molecules and other quantum objects The flow of electricity through molecules is explained at the boundary of physics and chemistry providing an authoritative introduction to molecular electronics for physicists and quantum transport for chemists Professor Lambert provides a pedagogical account of the fundamental concepts needed to understand quantum transport and thermoelectricity in molecular scale and nanoscale structures The material provides researchers and advanced students with an understanding of how quantum transport relates to other areas of materials modelling condensed matter and computational chemistry After reading the book the reader will be familiar with the basic concepts of molecular orbital theory and scattering theory which underpin current theories of quantum transport Key Features Introduces molecular electronics for physicists and quantum transport for chemists Presents a conceptual framework for understanding room temperature electron and phonon transport through molecules and other quantum objects Provides a pedagogical account of quantum interference enhanced electrical and thermal properties of single molecules and self assembled monolayers Provides readers with an understanding of how quantum transport relates to other areas of materials modelling condensed matter or computational chemistry Discusses concepts needed to engineer the properties of molecules and create new functions Includes MATLAB codes to allow the reader to expand the examples presented in the book

Quantum Transport Juli V. Nazarov,Yaroslav M. Blanter,2009 Quantum Transport Yuli V. Nazarov,Yaroslav M. Blanter,2009-05-28 Quantum transport is a diverse field sometimes combining seemingly contradicting concepts quantum and classical conduction and insulating within a single nanodevice Quantum transport is an essential and challenging part of nanoscience and understanding its concepts and methods is vital to the successful fabrication of devices

at the nanoscale This textbook is a comprehensive introduction to the rapidly developing field of quantum transport The authors present the comprehensive theoretical background and explore the groundbreaking experiments that laid the foundations of the field Ideal for graduate students each section contains control questions and exercises to check readers understanding of the topics covered Its broad scope and in depth analysis of selected topics will appeal to researchers and professionals working in nanoscience

Electronic Quantum Transport in Mesoscopic Semiconductor Structures Thomas Ihn, 2004-09-09 The physics of semiconductors has seen an enormous evolution within the last forty years Countless achievements have been made in scientific research and device applications have revolutionized everyday life We have learned how to customize materials in order to tailor their optical as well as electronic properties The ongoing trend toward device miniaturization has been the driving force on the application side and it has fertilized fundamental research Nowadays advanced processing techniques allow the fabrication of sub micron semiconductor structures in many university research laboratories At the same time experiments down to millikelvin temperatures allow researchers to anticipate the observation of quantum phenomena so far hidden at room temperature by the large thermal energy and strong dephasing The field of mesoscopic physics deals with systems under experimental conditions where several quantum length scales for electrons such as system size and phase coherence length or phase coherence length and elastic mean free path are comparable Intense research over the last twenty years has revealed an enormous richness of quantum effects in mesoscopic semiconductor physics which is typically characterized by an interplay of quantum interference and many body interactions The most famous phenomena are probably the integer and fractional quantum Hall effects the quantization of conductance through a quantum point contact the Aharonov Bohm effect and single electron charging of quantum dots

Quantum Transport in

One-dimensional Nanostructures Joseph Albert Sulpizio, 2011 One dimensional 1D electronic nanostructures comprise a class of systems that boast tremendous promise for both technological innovation as well as fundamental scientific discovery To fully harness their potential it is crucial to understand transport through 1D systems at the most fundamental quantum level In this thesis we describe our investigations down three avenues of quantum transport in 1D 1 ballistic transport in quantum wires 2 quantum capacitance measurements of nanostructures and 3 tunneling measurements in carbon nanotubes First we discuss measurements and modeling of hole transport in ballistic quantum wires fabricated by GaAs AlGaAs cleaved edge overgrowth where we find strong g factor anisotropy which we associate with spin orbit coupling and evidence for the importance of charge interactions indicated by the observation of 0.7 structure Additionally we present the first experimental observation of a predicted spin orbit gap in the 1D density of states where counter propagating spins constituting a spin current are accompanied by a clear signal in the conductance Next we present the development of a highly sensitive integrated capacitance bridge for quantum capacitance measurements to be used as a novel probe of 1D systems We demonstrate the utility of our bridge by measuring the capacitance of top gated graphene devices where we cleanly resolve

the density of states and also present preliminary measurements of carbon nanotube devices where we ultimately aim to extract their mobility Finally we discuss a set of transport measurements in carbon nanotubes designed to probe interactions between fermions in 1D in which top gates are used to introduce tunable tunnel barriers

Introduction To Semiconductor Device Modelling Christopher M Snowden,1998-09-29 This book deals mainly with physical device models which are developed from the carrier transport physics and device geometry considerations The text concentrates on silicon and gallium arsenide devices and includes models of silicon bipolar junction transistors junction field effect transistors JFETs MESFETs silicon and GaAs MESFETs transferred electron devices pn junction diodes and Schottky varactor diodes The modelling techniques of more recent devices such as the heterojunction bipolar transistors HBT and the high electron mobility transistors are discussed This book contains details of models for both equilibrium and non equilibrium transport conditions The modelling Technique of Small scale devices is discussed and techniques applicable to submicron dimensioned devices are included A section on modern quantum transport analysis techniques is included Details of essential numerical schemes are given and a variety of device models are used to illustrate the application of these techniques in various fields

Quantum Transport in Mesoscopic Systems David Sánchez,Michael Moskalets,2021-01-06 Mesoscopic physics deals with systems larger than single atoms but small enough to retain their quantum properties The possibility to create and manipulate conductors of the nanometer scale has given birth to a set of phenomena that have revolutionized physics quantum Hall effects persistent currents weak localization Coulomb blockade etc This Special Issue tackles the latest developments in the field Contributors discuss time dependent transport quantum pumping nanoscale heat engines and motors molecular junctions electron electron correlations in confined systems quantum thermo electrics and current fluctuations The works included herein represent an up to date account of exciting research with a broad impact in both fundamental and applied topics

Nanomaterials A.S Edelstein,R.C Cammaratra,1998-01-01 Nanomaterials Synthesis Properties and Applications provides a comprehensive introduction to nanomaterials from how to make them to example properties processing techniques and applications Contributions by leading international researchers and teachers in academic government and industrial institutions in nanomaterials provide an accessibl

Nanostructure Physics and Fabrication Mark A. Reed,Wiley P. Kirk,2012-12-02 Nanostructure Physics and Fabrication contains the contributions of an interdisciplinary group of specialists in nanometer scale fabrication physics of mesoscopic systems electronic transport and materials science brought together to discuss the current status of nanometer scale electronic structures These articles provide the most current assessment of this active and growing area of interest The introductory chapter provides comments and background material for those somewhat unfamiliar with this new area of research and serves as a condensed overview and summary of the contributions that follow Most current assessment of the field Articles by experts in the field Results presented here will impact the future of microelectronics

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Table of Contents Quantum Transport

1. Understanding the eBook Quantum Transport
 - The Rise of Digital Reading Quantum Transport
 - Advantages of eBooks Over Traditional Books
2. Identifying Quantum Transport
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Quantum Transport
 - User-Friendly Interface
4. Exploring eBook Recommendations from Quantum Transport
 - Personalized Recommendations
 - Quantum Transport User Reviews and Ratings
 - Quantum Transport and Bestseller Lists
5. Accessing Quantum Transport Free and Paid eBooks
 - Quantum Transport Public Domain eBooks
 - Quantum Transport eBook Subscription Services

- Quantum Transport Budget-Friendly Options
- 6. Navigating Quantum Transport eBook Formats
 - ePub, PDF, MOBI, and More
 - Quantum Transport Compatibility with Devices
 - Quantum Transport Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Quantum Transport
 - Highlighting and Note-Taking Quantum Transport
 - Interactive Elements Quantum Transport
- 8. Staying Engaged with Quantum Transport
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Quantum Transport
- 9. Balancing eBooks and Physical Books Quantum Transport
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Quantum Transport
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Quantum Transport
 - Setting Reading Goals Quantum Transport
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Quantum Transport
 - Fact-Checking eBook Content of Quantum Transport
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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