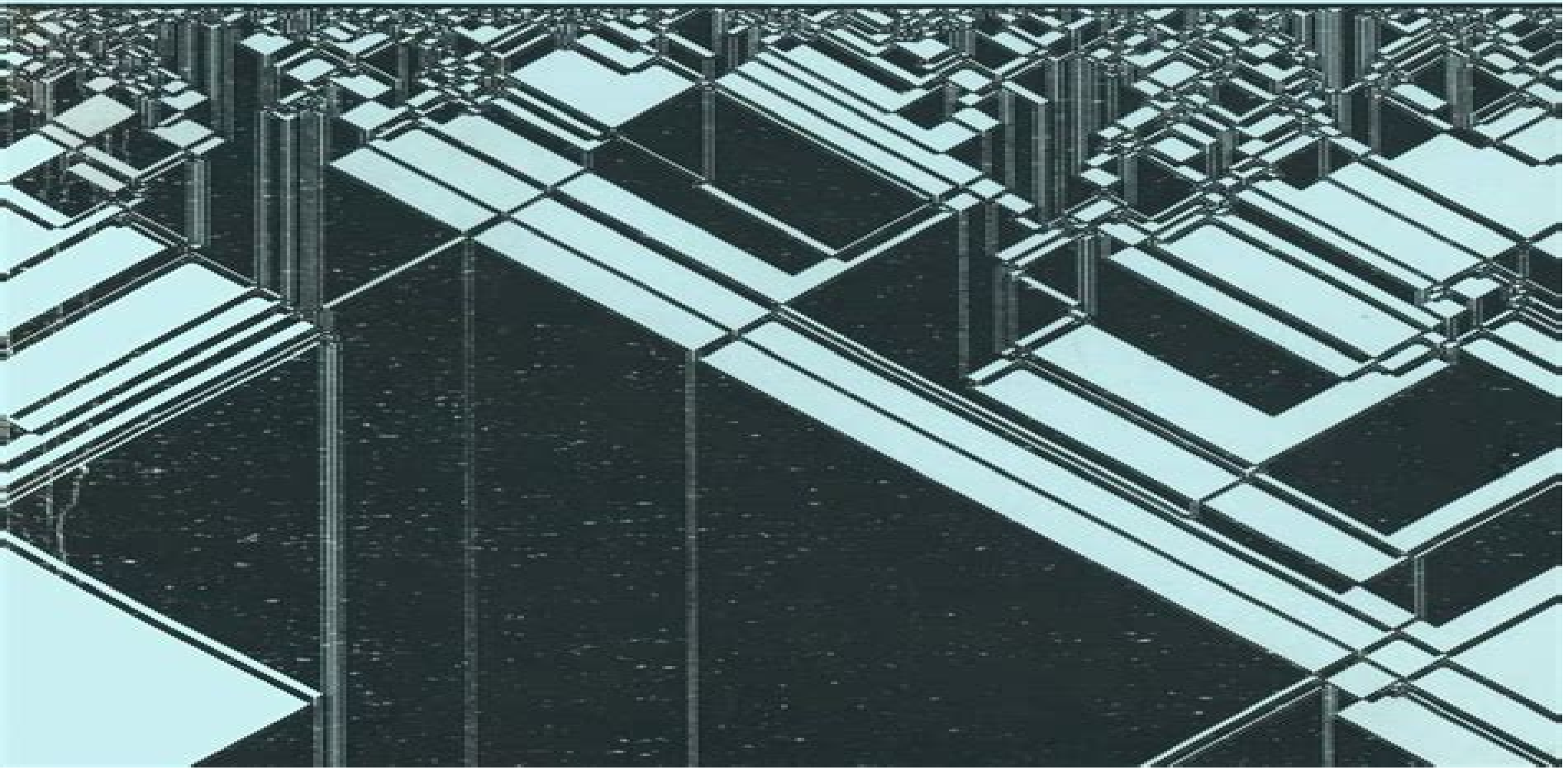
Physics of Solids and Liquids

Quantum Transport in Semiconductors

Edited by
David K. Ferry and Carlo Jacoboni



Quantum Transport In Semiconductors

Tillmann Christoph Kubis

Quantum Transport In Semiconductors:

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 Gen erally 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 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 in Semiconductor Nanostructures* Tillmann Christoph Kubis,2009 **Quantum Transport in Semiconductor Devices** DAVID K. ORIOLS FERRY (PROFESSOR XAVIER. WEINBUB, PROFESSOR JOSEF.),Xavier Oriols,Josef Weinbub,2023-11-21 This reference text presents a thorough discussion of the interface between quantum mechanics and real world device simulation with an emphasis on the use of particles in the simulation *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 *Physics of Nonlinear Transport in Semiconductors* David K. Ferry,John Robert Barker,C. Jacobini,2012-12-06 The area of high field transport in semiconductors has been of interest since the early studies of dielectric breakdown in various materials It really emerged as a sub discipline of semiconductor physics in the early 1960 s following the discovery of substantial deviations from Ohm s law at high electric fields Since that time it has become a major area of importance in solid state electronics as semiconductor devices have operated at higher frequencies and higher powers It has become apparent since the Modena Conference on Hot Electrons in 1973 that the area of hot electrons has ex tended weIl beyond the concept of semi classical electrons or holes in homogeneous semiconductor materials This was exemplified by the broad range of papers presented at the International Conference on Hot Electrons in Semiconductors held in Denton Texas in 1977 Hot electron physics has progressed from a limited phenomeno logical science to a full fledged experimental and precision theo retical science The conceptual base and subsequent applications have been widened and underpinned by the development of ab initio nonlinear quantum transport theory which complements and identifies the limitations of the traditional semi classical Boltzmann Bloch picture Such diverse areas as large polarons pico second laser excitation quantum magneto transport sub three dimensional systems and of course device dynamics all have been shown to be strongly interactive with more classical hot electron pictures Theory of Electron Transport in Semiconductors Carlo Jacoboni,2010-09-05 This book originated out of a desire to provide students with an instrument which might lead them from knowledge of elementary classical and quantum physics to moderntheoreticaltechniques for the analysisof electrontransport in semiconductors The book is basically a textbook for students of physics material science and electronics Rather than a monograph on detailed advanced research in a speci c area it intends to introduce the reader to the fascinating eld of electron dynamics in semiconductors a eld that through its applications to electronics greatly contributed to the transformationof all our lives in the second half of the twentieth century and continues to provide surprises and new

challenges The eld is so extensive that it has been necessary to leave aside many subjects while others could be dealt with only in terms of their basic principles The book is divided into ve major parts Part I moves from a survey of the fundamentals of classical and quantum physics to a brief review of basic semiconductor physics Its purpose is to establish a common platform of language and symbols and to make the entire treatment as far as pos ble self contained Parts II and III respectively develop transport theory in bulk semiconductors in semiclassical and quantum frames Part IV is devoted to semiconductor structures including devices and mesoscopic coherent s tems Finally Part V develops the basic theoretical tools of transport theory within the modern nonequilibrium Green function formulation starting from an introduction to second quantization formalism **Electronic Quantum Transport in Mesoscopic Semiconductor Structures** Thomas Ihn,2004-09-09 The physics of semiconductors has seen an enormous evolution within the last fty years Countless achievements have been made in scienti c 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 on ing trend toward device miniaturization has been the driving force on the appli tion 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 eld of mesoscopic physics deals with systems under experimental con tions 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 compa ble Intense research over the last twenty years has revealed an enormous richness of quantum effects in mesoscopic semiconductor physics which is typically charact ized 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 Modeling of Quantum Transport in Semiconductor Devices David K. Ferry,Harold L. Grubin,1994 Quantum Transport in Semiconductor Submicron Structures B. Kramer,2012-12-06 The articles in this book have been selected from the lectures of a NATO Advanced Study Institute held at Bad Lauterberg Germany in August 1995 Internationally well known researchers in the field of mesoscopic quantum physics provide insight into the fundamental physics underlying the mesoscopic transport phenomena in structured semiconductor inversion layers In addition some of the most recent achievements are reported in contributed papers The aim of the volume is not to give an overview over the field Instead emphasis is on interaction and correlation phenomena that turn out to be of increasing importance for the understanding of the phenomena in the quantum Hall regime and in the transport through quantum dots The present status of the quantum Hall experiments and theory is reviewed As a key example for non Fermi liquid behavior the Luttinger liquid is introduced including some of the most recent developments It is

not only of importance for the fractional quantum Hall effect but also for the understanding of transport in quantum wires Furthermore the chaotic and the correlation aspects of the transport in quantum dot systems are described The status of the experimental work in the area of persistent currents in semiconductor systems is outlined The construction of one of the first single electron transistors is reported The theoretical approach to mesoscopic transport presently a most active area is treated and some aspects of time dependent transport phenomena are also discussed **Advanced Research Workshop on Quantum Transport in Semiconductors** ,2002 A workshop was held on the topic of quantum transport in semiconductor devices This workshop brought together 17 lecturers and 35 other attendees for this purpose Quantum Transport in Semiconductor Devices David K Ferry,Xavier Oriols,Josef Weinbub,2023-11-21 This reference text presents a thorough discussion of the interface between quantum mechanics and real world device simulation with an emphasis on the use of particles in the simulation **Wokshop on Quantum Transport in Semiconductors[** ,2001 Theory of Transport Properties of Semiconductor Nanostructures Eckehard Schöll,2013-11-27 Recent advances in the fabrication of semiconductors have created almost un limited possibilities to design structures on a nanometre scale with extraordinary electronic and optoelectronic properties The theoretical understanding of elec trical transport in such nanostructures is of utmost importance for future device applications This represents a challenging issue of today s basic research since it requires advanced theoretical techniques to cope with the quantum limit of charge transport ultrafast carrier dynamics and strongly nonlinear high field ef fects This book which appears in the electronic materials series presents an over view of the theoretical background and recent developments in the theory of electrical transport in semiconductor nanostructures It contains 11 chapters which are written by experts in their fields Starting with a tutorial introduction to the subject in Chapter 1 it proceeds to present different approaches to transport theory The semiclassical Boltzmann transport equation is in the centre of the next three chapters Hydrodynamic moment equations Chapter 2 Monte Carlo techniques Chapter 3 and the cellular au tomaton approach Chapter 4 are introduced and illustrated with applications to nanometre structures and device simulation A full quantum transport theory covering the Kubo formalism and nonequilibrium Green s functions Chapter 5 as well as the density matrix theory Chapter 6 is then presented **Opto-electronic and Quantum Transport Properties of Semiconductor Nanostructures** Matthias Sabathil,2005 **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 1 0 15 lm 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 *Quantum Transport Effects in Semiconductors* J. G. Boulton,1983 **High Field Quantum Transport Theory in Semiconductors** David Lowe,1983 *Topics in High Field Transport in Semiconductors* Kevin F. Brennan,P. Paul Ruden,2001 This book examines some of the charge carrier transport issues encountered in the field of modern semiconductor devices and novel materials Theoretical approaches to the understanding and modeling of the relevant physical phenomena seen in devices that have very small spatial dimensions and that operate under high electric field strength are described in papers written by leading experts and pioneers in this field In addition the book examines the transport physics encountered in novel materials such as wide band gap semiconductors GaN SiC etc as well as organic semiconductors Topics in High Field Transport in Semiconductors provides a comprehensive overview that will be beneficial to newcomers as well as engineers and researchers engaged in this exciting field **Monte Carlo Analysis of Quantum Transport and Fluctuations in Semiconductors** Carlo Jacoboni,MODENA UNIV (Italy),1986 The present report contains technical matter related to the research performed on two different subjects The first part concerns with quantum transport in semiconductors A unified review of the work already published in the literature is given together with some attempts to generalize Monte Carlo methods to quantum transport within the Liouville formulation The second part concerns with fluctuations of carrier velocities and energies both in stationary and transient regime described by means of the correlation function method An analysis of the results obtained through a Monte Carlo procedure for covalent and polar materials yields a deep physical picture of the effect of the scattering mechanisms phonon and carrier carrier interactions on the transport properties Keywords Monte Carlo Charge Transport Quantum Transport Fluctuations Semiconductor Physics Master Equation Boltzmann Equation Langevin Equation Green Functions Wigner Function Drift Velocity Mean Energy Stationary Regimes Transient Regimes Diffusivity Autocorrelation Functions Relaxation effects Electron electron Interaction

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