Preface

The physics of semiconductors has seen an enormous evolution within the last fifty 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.

The sheer unlimited versatility of materials and processing techniques does not only sustain a flourishing field of physics but still inspires a large community of researchers to develop more and more challenging visions that may be realized in semiconductor systems. Some top issues are strongly correlated mesoscopic electronic systems, spins in mesoscopic systems and spintronics, phase-coherence, controlled entanglement, controlled dephasing, and quantum information processing.

This book tries to give some insight into recent research work in the field of electron transport in mesoscopic semiconductors by covering three selected topics. Since no selection of topics in this broad field could ever be representative, it was mainly dictated by my own research pursued over the last years. However, an introductory historical part I was added in order to give the non-specialist a chance to see which developments form the basis for current research.

Part II of this book is devoted to the possible metal-insulator transition in two-dimensional systems at zero magnetic field and low temperatures. Although the existence of novel interaction-dominated metallic ground states is still under debate, the topic has initiated substantial research on the experimental side as well as in theory over the last years.

In part III electron transport through semiconductor quantum dots is introduced and certain aspects of recent research are discussed. In particular, it treats electron transport through a Coulomb blockaded quantum ring system in which Aharonov–Bohm-type effects allow a surprisingly detailed understanding of the energy spectrum. In addition, the question of the ground-state spins in conventional singly connected quantum dots is addressed.

Part IV gives an overview over novel setups and experiments that aim at the local investigation of mesoscopic system's interiors by utilizing scanning probe techniques at cryogenic temperatures. The "marriage" of scanning probes, which are subject of a research field on their own, and mesoscopic semiconductor physics has turned out to be an extremely demanding enterprise for two reasons: first, it is experimentally very challenging to operate scanning force microscopes at temperatures where mesoscopic physics is observed in semiconductors and second, there are almost no detailed theories that allow the interpretation of scanned images or that teach the experimentalists how exactly to perform experiments in order to get meaningful results. However, exactly these two aspects have made research in this direction so exciting.

Sincere thanks are given to all those who have contributed to the presented work, in particular to those talented young scientists who have devoted some years of their career to this fascinating field of mesoscopic electronics. Although many more people are acknowledged at the end of this book, already at this point I wish to thank the key-players in our team at ETH Zurich, Volkmar Senz, Andreas Fuhrer, Stefan Lindemann, Jörg Rychen, Tobias Vancura, and Klaus Ensslin.

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