Preface

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. On the other hand, the influence of interactions on quantities such as the conductance and conductivity remains one of the most controversial issues of recent years. Progress has been achieved partly in the understanding of new quasiparticles such as skyrmions, composite fermions, and new states of the interacting electron gas (e.g., Tomonaga–Luttinger liquids), both theoretically and in experiments. At the same time, it has now become clear that for fast processes in small structures not only the interaction but also the non-equilibrium aspect of quantum transport is of fundamental importance. It is also apparent now that, in order to understand a major part of the experimental results, transport theories are required that comprise both the non-equilibrium and the interaction aspect, formulated in the framework of a physical language that was born almost exactly one century ago: quantum mechanics.

This volume contains the proceedings of the 219th WEH workshop 'Interactions and transport properties of low dimensional systems' that took place on July 27 and 28, 1999, at the Warburg–Haus in Hamburg, Germany. Talks were given by leading experts who presented and discussed recent advances for the benefit of participants from all over the world, among whom were many young students. This is one reason why the present volume is more than simply a state-of-the-art collection of review articles on electronic properties of interacting lower dimensional systems. We have also tried to achieve a style of presentation that allows an advanced student or newcomer to use this as a textbook. Further study is facilitated by the many references at the end of each article. Thus we encourage all those interested to use this book together with pencil and sometimes the further reading, to gain an entry into this fascinating field of modern physics.

The articles in Part I present the physics of interacting electrons in one-dimensional systems. Here, one of the key issues is the identification of power-laws appearing as a function of energy scales such as the voltage, the frequency, or the temperature. A generic theoretical description of the physics of such systems is provided by the Tomonaga–Luttinger model, where in general power-law exponents depend on the strength of the electron–electron interaction. Further important issues are the proper definition of the conductance of interacting systems, the experimental verification of the predictions, and the search for new phases in quantum wires, as discussed in detail in the individual contributions.

The articles in Part II present an introduction to non-equilibrium transport through quantum dots, a survey of spin-related effects appearing in electronic transport properties, and new phenomena in two-dimensional systems under quantum Hall conditions, i.e. in strong magnetic fields.

All the contributions contain new and surprising results. One can definitely predict that many more novel aspects of the physics of 'interactions plus non-equilibrium in low dimensions' will emerge in the future. At this point, let me express the wish that this book will help to motivate readers to take part in this fascinating, rapidly developing field of physics. I would like also to use the present opportunity to thank all the participants and the speakers of the workshop for their contributions, and to acknowledge the friendly support of the WE Heraeus foundation.

Hamburg, November 1999 *Tobias Brandes*