

## Preface

Exploring new orders of magnitude seems to be a part of human nature. This tendency is reflected even in the language. If a particular “megadeal” is really stunning, we feel more and more obliged to call it a “gigadeal”. It will not take long before the first “terastar” pops up! Each new generation of particle colliders, telescopes, or lasers, in fact of almost any scientific device or technique you can think of, extends the accessible interval of a physical quantity. It is rather the rule than the exception that novel phenomena are discovered in such a process, some of which have been anticipated, others of which have not. Such an evolution seems to gain speed as soon as it gets classified as useful, besides pure scientific interest. It is of course debatable what exactly should be considered as “useful”.

In any case, the miniaturization of electronic circuits during the past 50 years has been both scientifically rewarding and useful in our daily life. It is certainly not necessary to support this statement by examples. Scientifically, however, the expression “microstructure” no longer fuels our imagination. Meanwhile, the really exciting electronic circuits are *nanostructures*. As this name already suggests, nanostructures are objects with structures in the nanometer (nm) regime, which can mean just 1 nm, but also just a little less (in fact, in some cases, even somewhat more) than 1000 nm. The point of nanostructure science is that, within the last two decades, tremendous progress has been made in fabricating, controlling and understanding structures in this size regime. This is true for a wide variety of fields, including, for example, gene technology, crystal growth or microchip – excuse me, nanochip – fabrication. The resulting novel possibilities at hand are really breathtaking and get heavily explored by a significant fraction of the scientific community. In many cases, having control over the size and shape of an object in the nanometer regime means being able to control its chemical and/or physical properties. For example, the size of a semiconductor nanocluster determines its optical emission spectrum via size quantization; while from introductory solid state physics lectures, we have learned that this property is related to the bandgap, an intrinsic feature of the material. By now, the size reduction has actually

reached dimensions that are of interest for chemistry and biology, and there is a rapidly growing overlap. For example, you can think of an ionic channel (they reside in cell membranes and control the electrochemical potential of cells by selectively transferring certain types of ions across the membrane) as a molecular transistor. On the other hand, nanostructure physicists have started to use DNA strands as wires and templates for nanocircuit fabrication.

One branch of nanoscience deals with the electronic transport properties of solid state nanostructures. This field is often referred to as “mesoscopic transport”, an expression which indicates that the explanations for the observed transport phenomena must be sought somewhere in between microscopic and macroscopic models. The purpose of the present book is to introduce the reader to this topic from an experimental point of view. “The reader” is hereby assumed to be a student of physics or a related field, who has just finished introductory courses, in particular those on solid state physics and quantum mechanics, and plans to study nanoscience more closely. The reader is picked up at the knowledge he/she is likely to have, and a ride is given to ongoing research activities in the field of mesoscopic transport. Along the way, the elementary concepts and nanostructures are introduced.

Selecting illustrative experiments for such a purpose is of course a highly subjective matter. The author has tried to pick particularly instructive examples well known to him, which can furthermore be explained within the scope of this book. These examples have thus not necessarily been of high relevance for the evolution of the field, and I apologize for this shortcoming. It should be remarked that, in some of the figures, the original data have been redrawn for better reproduction quality and for a consistent presentation.

The text contains a somewhat unusual feature, namely “papers” in the exercises sections. Their purpose is to encourage the student to go through selected, usually quite recent, original publications. They are referred to by [P chapter.number] in the text. The student should be able to summarize the beef of such a paper in a 15 minute talk. The reader is strongly encouraged actually to do this. Besides collecting complementary information and getting exposed to different styles of presentation, the experience of being able to understand the stuff written down not in a textbook but in an original paper can be highly motivating.

I hope that after going through the text, the reader will not only be able to join with some confidence an experimental research group working in this field, but also feel well prepared for more advanced theoretical lectures on mesoscopic physics.

This book, and with it the author, has enjoyed a lot of encouragement and support from many sides. I would like to thank particularly Hermann Grabert and Wolfgang Häusler, who read through parts of the manuscript and made many valuable comments. I am grateful to my colleagues Klaus Ensslin,

Andreas Fuhrer, Miha Furlan, Ryan Held, Thomas Ihn, Silvia Lüscher, Jörg Rychen, and Volkmar Senz for countless fruitful discussions and stimulating ideas. Special thanks go to those who supplied figures for this book, namely Günther Bauer, Mildred Dresselhaus, Andreas Fuhrer, Theo Geisel, Adam Hansen, Roland Ketzmerick, Anupam Madhukar, Andy Sachrajda, Elke Scheer, Jürgen Smet, and Horst Stormer. Furthermore, I thank my students, whose critical but always constructive comments have shaped and improved the presentation of the material. Last, but not least, I thank my wife Ulrike. With her tremendous energy and selfless support, she managed to supply the refuge I needed to transform my disorganized lecture notes into a book.

Thomas Heinzl, Düsseldorf, 2006