

Preface

For the first time in monographic literature, the present book provides a broad panorama of the physics of quantum rings with emphasis on *modern advancements* in theoretical and experimental investigations of semiconductor quantum rings. It is written in a style which makes these issues accessible to theoretical physicists, experimental researchers, and technologists with different levels of experience: from graduate and PhD students to experts. The book is also intended to convey the fascination of quantum rings to specialists in other disciplines: mathematics, chemistry, electronic and optical engineering, and information technologies. Our goal is that this book will succeed in invigorating research interests towards the further development of fundamental insight in and applications of quantum rings.

It starts with an introduction into the fundamental physics of quantum rings as a heuristically unique playground for the quantum-mechanical paradigm and a concise overview of the state-of-the-art in the field, with a particular emphasis on the quantum interference phenomena like the Aharonov-Bohm effect in quantum rings (Chap. 1). The book consists of three main parts, though the borders between them are conventional: Part I. Fabrication, characterization and physical properties, Part II. Aharonov-Bohm effect for excitons and Part III. Theory.

The *first part* represents three advanced methods of fabrication of quantum rings: self-organized growth, droplet epitaxy and lithographic patterning, as well as their characterization based on scanning-probe-microscopy. It opens with Chap. 2 (by Wen Lei and Axel Lorke) and Chap. 3 (by Jorge M. García, Benito Alén, Juan Pedro Silveira and Daniel Granados) representing fundamentals of the self-organized growth and optical properties of semiconductor quantum rings. In Chap. 4 (by myself, Vladimir N. Gladilin, Jozef T. Devreese and Paul M. Koenraad) we discuss how the modern characterization of self-assembled InGaAs/GaAs quantum rings using X-STM has allowed for a development of an adequate model of their shape, which quantitatively explains the Aharonov-Bohm effect observed in the magnetization. Self-organized formation of highly distinct GaSb/GaAs quantum-ring structures and their X-STM characterization are presented in Chap. 6 (by Andrea Lenz and Holger Eisele).

Scanning-probe electronic imaging of lithographically patterned quantum rings, which is discussed in Chap. 5 (by Frederico R. Martins, Hermann Sellier, Marco G. Pala, Benoit Hackens, Vincent Bayot and Serge Huant), can access to the intimate properties of buried electronic systems. Another promising way of controllable self-assembled fabrication of quantum rings—by droplet epitaxy—is overviewed in Chap. 7 (by Jiang Wu and Zhiming M. Wang) with emphasis on ordered arrays and in Chap. 8 (by Stefano Sanguinetti, Takaaki Mano and Takashi Kuroda), where the focus is on semiconductor quantum-ring complexes.

The *second part* deals with the Aharonov-Bohm effect for multi-electron systems, in particular, for excitons and plasmons. In Chap. 9, Alexander V. Chaplik and Vadim M. Kovalev review theoretical investigations on novel versions of the Aharonov-Bohm effect in quantum rings, including that for electronic Wigner molecules, polarized neutral and charged excitons, and polarons, as well as its manifestations in the longitudinal magnetoresistance. Also, the role of the spin-orbit interaction in the electronic properties of quantum rings is revealed. Theory meets experiment on the Aharonov-Bohm effect for neutral excitons in quantum rings in Chap. 10 (by Marcio D. Teodoro, Vivaldo L. Campo, Jr., Victor Lopez-Richard, Euclydes Marega, Jr., Gilmar E. Marques and Gregory J. Salamo). Remarkably robust optical Aharonov-Bohm effect occurs in type-II quantum dots presented in Chap. 11 (by Ian R. Sellers, Igor L. Kuskovsky, Alexander O. Govorov and Bruce D. McCombe). Chapter 12 (by Fei Ding, Bin Li, François M. Peeters, Val Zwiller, Armando Rastelli and Oliver G. Schmidt) describes the observation and manipulation of Aharonov-Bohm-type oscillations in a single quantum ring.

The *third part* represents advancements in theory of quantum rings. The effects of a tensile-strained insertion layer on strain and the electronic structure of quantum rings are analyzed in Chap. 13 (by Pilkyung Moon, Euijoon Yoon, Won Jun Choi, Jae Dong Lee and Jean-Pierre Leburton) using the model advanced in Chap. 4. The basic approaches to theoretical modeling of electronic and optical properties of semiconductor quantum rings are overviewed by Oliver Marquardt in Chap. 14; it can also serve as a tutorial for students. A survey on Coulomb interaction in finite-width quantum rings is provided in Chap. 15 (by Benjamin Baxevanis and Daniela Pfannkuche). Booming studies on general topological aspects of quantum rings are illuminated by Benny Lassen, Morten Willatzen and Jens Gravesen in Chap. 16 on differential-geometry methods applied to rings and Möbius nanostructures. In Chap. 17, Carlos Segarra, Josep Planelles and Juan I. Climente discuss effects of hole mixing in semiconductor quantum rings and show that the strong strain potential may compete against the band-offset potential in quantum rings. Engineering of electron states and spin relaxation in quantum rings and quantum dot-ring nanostructures is reviewed in Chap. 18 (by Marcin Kurpas, Elzbieta Zipper and Maciej M. Maška).

The *main message* of the present book is that the front-line methods of fabrication and characterization of quantum rings together with the sophisticated cutting-edge theoretical research have allowed for accumulation of a significant thesaurus of fundamental information on their behavior. This highly diversified knowledge underpins numerous suggestions for prospective applications of quantum rings as a

highly tunable elemental base for future device design and optimization, in particular, in optoelectronics and spintronics, magnetic memory devices, photonic sources and detectors, and information storage and processing.

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Vladimir M. Fomin



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