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Superlattices and Other Heterostructures

Symmetry and Optical Phenomena

Translated by G.P. Skrebtsov

Second Edition
With 85 Figures

Springer

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In Memoriam

our teacher, Professor

A.I. Anselm

1905–1988

Preface

Since the first edition of this book was published, the 22nd and 23rd International Conferences on the Physics of Semiconductors (ICPS) have been held, in Vancouver, Canada, and Berlin, Germany, respectively. Representing, as usual, the state of the art of semiconductor physics, the recent ICPSs have confirmed the significance of heterostructures and superlattices and showed the rapidly increasing role of small quantum systems. The main goal of this book is to demonstrate the efficiency of symmetry considerations in an analysis of optical phenomena in heterostructures with quantum wells and superlattices. With further progress in growth technology, the importance of the symmetry approach will become even more evident. We also expect this treatment to provide the framework within which future research into quantum wires and dots may develop. We hope that this monograph will prove useful for both researchers working in the field of semiconductors and semiconductor devices and students specializing in materials sciences.

In the preparation of this second edition we have corrected errors and misprints and added references to recent publications, including those on quantum microcavities and four-wave mixing in heterostructures.

St. Petersburg, Russia
January 1997

E.L. Ivchenko
G.E. Pikus

Preface to the First Edition

For a long time we had been contemplating the possibility of writing a book about optical phenomena in semiconductors in which the various optical phenomena would be considered from the standpoint of the theory of symmetry. We had planned to start with a short introduction into the theory of symmetry as the basis for expounding the methods for calculating the spectra of electrons, excitons and phonons in semiconductors. Using the results obtained we can then discuss the absorption and reflection of light in interband transitions including the exciton and polariton effects, electro- and magneto-optical phenomena, IR absorption and reflection, cyclotron and electron-spin resonance, light scattering by free and bound carriers and optical and acoustic phonons, polarized photoluminescence, optical spin orientation of electrons and excitons, electron alignment in momentum space, nonlinear optical and photogalvanic effects, with particular emphasis on the phenomena determined by crystal symmetry.

However, by the time the writing of such a book took place, the interest in the optics of semiconductors had shifted from bulk crystals to artificially produced low-dimensional systems. Having mastered the methods of fabricating complex synthetic structures, physicists imagined themselves capable of creating at will new objects with programmed properties and, predictably, could not resist the temptation to do so. As always, though, *Nature* proved more imaginative than *Man*, and what physicists had foreseen was only a part of what was to be revealed later.

In a book, it would hardly be possible to avoid describing the optical properties of these new objects. At the same time, an analysis of the properties of both low-dimensional and bulk crystals would require too extended a discussion. We decided therefore to modify the original idea, considering all of the above phenomena only for the quantum wells, superlattices and other heterostructures, and using them to illustrate the variety of polarization spectroscopic methods developed in the optics of semiconductors. Even after narrowing the topic, however, the number of works to be dealt with was obviously too large. Thus, we have restricted ourselves to a comparatively small number of studies which, in our opinion, illustrate most clearly the relation between the symmetry and optical phenomena, in order to follow consistently the road from the theory of symmetry to the description of particular physical phenomena; we hope that such a strategy will offer the reader a problem-solving tool. Hence, have followed, to a considerable extent, the pattern of the monograph *Symmetry and Strain-Induced Effects in Semiconductors* (by one of the authors together with G.L. Bir), but not expounding in detail on the group theory. Instead, we give only those results necessary for the understanding of subsequent chapters, including the required reference tables.

The literature used in the preparation of the book as well as publications which broaden and expand the material are collected partly in the list of references and partly under additional reading.

A special note concerns the nomenclature used in the monograph: the direction along the principal axis of a superlattice or a quantum well structure is denoted by the symbol $\|$, for instance, $a_{\|}$, $M_{\|}$, and the direction perpendicular to the axis, by $\perp$, for example, $k_{\perp}$, $m_{\perp}$. This is in agreement with the system of notation accepted for uniaxial crystals or many-valley semiconductors with anisotropic valleys. The reader should keep this in mind, since many publications on low-dimensional systems make use of the reverse nomenclature.

Finally, the authors wish to express their sincere gratitude to Dr. G.P. Skrebtsov, who undertook the not easy task of translating the manuscript.

St. Petersburg, Russia
August 1994

E.L. Ivchenko
G.E. Pikus

Contents