

Preface to the Second Edition

In this second revised edition several parts of the first edition have been rewritten and extended. This is particularly the case for Chaps. 4, 6 and 8, which represent the central parts of the book. The presentation of numerical results concerning quantum-electrodynamical (QED) effects in combination with electron correlation is extended and now includes radiative QED effects (electron self-energy, vertex correction and vacuum polarization), involving the use of Feynman and Coulomb gauges.

A new section (Part IV) has been added, dealing with QED effects in *dynamical processes*. It turned out that the Green's operator, introduced primarily for structure problems, is particularly suitable also for dealing with dynamical processes, when bound states are involved. Here, certain singularities may appear of the same kind as in dealing with static processes, leading to so-called *model-space contributions*. These cannot be handled with the standard S-matrix formulation, which is the normal procedure for dynamical processes involving only free-particle states. This has led to a modification of the optical theorem applicable also to bound states, where the S-matrix is replaced by the Green's operator.

In addition, a number of misprints and other errors have been corrected for, and I am grateful to all readers who have pointed out some of them to me.

I wish to express my gratitude to Prof. Walter Greiner, Frankfurt, and to the Alexander von Humboldt Foundation for moral and economic support during the entire work with this book.

I am very grateful to my coworkers, Sten Salomonson, Daniel Hedendahl and Johan Holmberg, for valuable cooperation and for allowing me to include results that are unpublished or in the process of being published.

On behalf of our research group of theoretical Atomic Physics at the University of Gothenburg, I wish to express our deep gratitude to Horst Stöcker and Thomas Stöhlker at GSI, Darmstadt, as well as to the Helmholtz Association for moral and financial support during the final phase of this project, which has been of vital importance for the conclusion of the project.

Gothenburg

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Preface to the First Edition

It is now almost 30 years since the first edition of my book together with John Morrison, *Atomic Many-Body Theory* [124], appeared, and the second edition appeared some years later. It has been out of print for quite some time, but fortunately it has recently been made available again by a reprint by Springer Verlag.

During the time that has followed, there has been a tremendous development in the treatment of many-body systems, conceptually as well as computationally. Particularly the relativistic treatment has expanded considerably, a treatment that has been extensively reviewed recently by Ian Grant in the book *Relativistic Quantum Theory of Atoms and Molecules* [79].

Also, the treatment of quantum-electrodynamical (QED) effects in atomic systems has developed considerably in the past few decades, and several review articles have appeared in the field [130, 159, 226] as well as in the book by Labzowsky *et al.*, *Relativistic Effects in Spectra of Atomic Systems* [114].

An impressive development has taken place in the field of many-electron systems by means of various coupled-cluster approaches, with applications particularly on molecular systems. The development during the past 50 years has been summarized in the book *Recent Progress in Coupled Cluster Methods*, edited by Čársky, Paldus and Pittner [246].

The present book is aimed at combining the atomic many-body theory with quantum electrodynamics, which is a long-sought goal in quantum physics. The main problem in this effort has been that the methods for QED calculations, such as the S-matrix formulation, and the methods for many-body perturbation theory (MBPT) have completely different structures. With the development of the new method for QED calculations, the *covariant evolution operator formalism* by the Gothenburg Atomic-Theory group [5], the situation has changed, and quite new possibilities has appeared to formulate a unified theory.

The new formalism is based on field theory, and in its full extent the unification process represents a formidable problem, and we can in the present book describe only how some steps towards this goal can be taken. The present book will be largely based upon the previous book *Atomic Many-Body Theory* [124], and it is

assumed that the reader has absorbed most of that book, particularly Part II. In addition, the reader is expected to have basic knowledge in quantum field theory, as found in books like *Quantum Theory of Many-Particle Systems* by Fetter and Walecka [67] (mainly parts I and II), *An Introduction to Quantum Field Theory* by Peskin and Schroeder [194], and *Quantum Field Theory* by Mandl and Shaw [143].

The material of the present book is largely based upon lecture notes and recent publications by the Gothenburg Atomic-Theory group [86, 89, 130–132], and I want to express my sincere gratitude particularly to my previous co-author John Morrison and to my present coworkers, Sten Salomonson and Daniel Hedendahl, as well as to the previous collaborators Ann-Marie Pendrill, Jean-Louis Heully, Eva Lindroth, Björn Åsén, Hans Persson, Per Sunnergren, Martin Gustavsson and Håkan Warston for valuable collaboration.

In addition, I want to thank the late pioneers of the field, Per-Olov Löwdin, who taught me the foundations of perturbation theory some 40 years ago, and Hugh Kelly, who introduced the diagrammatic representation into atomic physics—two corner stones of the later developments. Furthermore, I have benefitted greatly from communications with many other national and international colleagues and friends (in alphabetic order), Rod Bartlett, Erkki Brändas, Gordon Drake, Ephraim Eliav, Stephen Fritzsche, Gerald Gabrielse, Walter Greiner, Paul Indelicato, Karol Jankowski, Jüürgen Kluge, Leonti Labzowsky, Peter Mohr, Debashis Mukherjee, Marcel Nooijen, Joe Paldus, Vladimir Shabaev, Thomas Stöohlker, Gerhard Soff[†], Joe Sucher, Peter Surjan and many others.

The outline of the book is the following. The main text is divided into three parts. Part I gives some basic formalism and the basic many-body theory that will serve as a foundation for the following text. In Part II three numerical procedures for calculation of QED effects on bound electronic states are described, the S-matrix formulation, the Green's function and the Green's operator methods. A procedure towards combining QED with MBPT is developed in Part III. Part IV contains a number of appendices, where basic concepts are summarized. Certain sections of the text that can be omitted at first reading are marked with an asterisk (*).

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A New Field-Theoretical Approach

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