Preface

The prospect of a fourth edition of *Quantum Dissipative Systems*, almost twenty years after initial publication, and four years after publication of the third edition, shows on the one hand that the field is rapidly developing and on the other hand that the book has been paid the compliment of growing use as a text since it appeared for the first time.

In preparing the fourth edition I have tried to sustain as much as possible the advantages of the previous editions while taking into account developments in the subject itself and its applications to other fields. It was a persistent intention of mine to escalate the pedagogical objectives. What has emerged is a thorough revision and a very considerable enlargement of the third edition to which about 60 pages have been added. The bibliography has undergone similar expansion, which reflects the enormous advance in this field in the four years since the third edition. Hardly a passage of the text has been left untouched with the aim of enhancing physical insights and clarity. The advanced formal techniques retained are in my opinion essential as to avoid that the reader must take anything on trust. At the same time I hope that the book is relatively easily readable by, for example, beginning graduate students in theory, or by a general readership with a background in quantum statistical physics. The major changes are of various kinds.

In Part I new sections have been added. They deal with ergodicity and treat a scheme in which stochastic non-Markovian quantum dynamics based on the unraveled influence functional is combined with semiclassical propagation within the frozen Gaussian approximation. The section on the harmonic oscillator bath with linear coupling has been augmented by subsections on the fractional Langevin equation and on the problem of a charged particle interacting with the radiation field.

The major additions in Part II are as follows. The chapter on the damped linear oscillator has been extended by a section on quantum mechanical master equations for the reduced density matrix. Further subsections dealing with radiation damping and with thermodynamic properties (e.g., internal energy, free energy and entropy) of the damped quantum oscillator have been added. The chapter on quantum Brownian free motion has been augmented by a section on the partition function and on thermodynamic properties. Further, a section on electron decoherence in a disordered conductor has been subjoined.

In Part IV, the chapter on the dissipative two-state dynamics has been rearranged and extended considerably in order to improve clarity. Now, there is a chapter on the basics and methods, and a chapter dealing with explicit results in various regimes of the parameter space. New sections on the pure dephasing regime and on decoherence resulting from $1/f$ noise have been appended.

Part V now contains a chapter on twisted partition functions for the dissipative multi-state system in the field theory limit. This includes derivation of the exact scaling solution for the partition function using properties of Jack symmetric functions and presentation of a conjecture by which the nonlinear conductance can be extracted from the the twisted partition function. This chapter complements the chapter on duality symmetry by giving a different perspective.

Errors that I have caught, or which have been pointed out to me, have been corrected. I hope that not too many new ones have crept into the revised material. I shall be very grateful to any reader who brings such deficiencies to my attention.

The selection made here represents something of a personal compromise. During recent years several topics, in particular those connected with quantum state engineering and quantum computing, have undergone enormous expansion both on the theoretical and experimental side. I am very conscious that the coverage of most recent developments in these fields is far from being complete. One area omitted deserves special mention – decoherence and relaxation in quantum gases. The importance of the field is without question, but I felt that an adequate treatment deserves a separate book.

An unforeseen event deferred the delivery by several months. I am very grateful to the responsible editor Kim Tan of World Scientific for her continuous advice and patience.

Finally, I would like to thank many colleagues and readers who made valuable remarks on previous editions. Particular thanks are due to Doron Cohen, Giuseppe Falci, Hermann Grabert, Milena Grifoni, Frank Großmann, Gert-Ludwig Ingold, Elisabetta Paladino, Gerd Schön, Udo Seifert, Jürgen Stockburger, and Andrei Zaikin for their comments and suggestions.

Stuttgart
November 2011   *Ulrich Weiss*

Preface to the Third Edition

In the fourteen years since the appearance of the first edition, the subject kept freshness. There have been interesting theoretical progress, important new applications and lots of stunning new experiments in the field.

The present edition of *Quantum Dissipative Systems* reflects two endeavors on my part: the improvement and refinement of material contained already in the second edition; the addition of new topics (and the omission of few).

The emphasis and major intensions are still the same, but there are changes, augmentations and additions. The major extensions, altogether about 60 pages, are: Chapter 3 contains a more detailed discussion of the quasiclassical Langevin equation and a subsection on Josephson flux and charge qubits. Chapter 4 gives wider space to the basics of path integration and to the treatment of an electromagnetic environment. Chapter 5 discusses the stochastic unraveling of path integrals for the reduced density matrix. Chaper 6 gives an extended discussion of the damped quantum harmonic oscillator. It includes discussion of internal energy, purity, and uncertainty. Chapter 15 presents a generalization of the Smoluchowski diffusion equation which includes quantum effects. Chapter 20 offers a broader discussion of single-charge tunneling in the weak-tunneling or Coulomb blockade regime. Chapter 21 discusses relaxation and decoherence in the spin-boson model at zero temperature. It presents analytical results for the relaxation and decoherence rate at general damping strength which cover the entire regime extending from weak to strong tunneling. Chapter 24 includes a discussion of the full counting statistics for Poissonian quantum transport and presents many analytical results available in special cases. Chapter 25 presents the scaling-invariant solution of the full counting statistics in diverse limits and discusses application to charge transport in Josephson junctions. Chapter 26 gives an extended discussion of charge transport in quantum impurity systems, including full counting statistics. It points out an intimate connection of these systems with models for coherent conductors and with others discussed in the preceding Chapters 23 – 25. The bibliography is updated.

This new edition has benefited from comments, suggestions and criticisms from many students and colleagues. Among those to whom I owe specific debt of gratitude are Holger Baur, Pino Falci, Hermann Grabert, Milena Grifoni, Yuli Nazarov, Elisabetta Paladino, Jürgen Stockburger, and Ruggero Vaia.

It is a pleasure to thank the students P. Diemand and A. Herzog for proofreading and tracking down misprints. I also wish to thank the responsible editor Kim Tan for advice and patience until completion of the third edition. Finally, I am grateful to my wife Christel for her sympathy and constant encouragement.

Stuttgart
October 2007   *Ulrich Weiss*

Preface to the Second Edition

Since the first publication of this book in 1993, there have been enormous research activities in quantum dissipative mechanics both experimentally and theoretically. For this reason, it has been highly desirable after the book has been sold out almost three years ago to undergo a number of extensions and improvements. I have been encouraged by the positive reception of this book by a large community and by many colleagues to write not simply an updated second edition. What came out now after all is almost a new book of roughly double content.

In an extensive rewriting, the 19 Chapters of the First Edition have been expanded by about one third to better meet the desires of both the newcomers to the field and the advanced readership, and I have added 7 new chapters. The most relevant extensions are as follows. In the first part, I have added a section on stochastic dynamics in Hilbert space and I have extended the discussion of relevant microscopic global models considerably. Now, there are also treated acoustic phonons with two-phonon coupling, a microscopic model for tunneling between surfaces, charging and environmental effects in normally conducting and superconducting tunnel junctions, and nonlinear quantum environments. Part II now contains an extended discussion of the damped harmonic oscillator (e.g., a study of the density of states is added), and new chapters on the thermodynamic variational approach and variational perturbation expansion method, and on the quantum decoherence problem. Part III, which deals with quantum-statistical decay, is extended by two chapters. In the new edition, the turnover theory to the energy-diffusion limited regime is discussed, and the treatment of dissipative quantum tunneling has been extended and improved. Ample space is now provided in Part IV to a thorough discussion of the dissipative two-state system. A number of new results on the thermodynamics and dynamics of this archetypal system are presented. An extensive discussion of electron transfer in a solvent, incoherent tunneling in the nonadiabatic regime, and single-charge tunneling is provided in a unified framework. Regarding dynamics, new sections on exact master equations, improved approximation schemes, and recent results on correlation functions have been written, and a new chapter on the driven dissipative two-state is included. Part V, which deals with the dissipative multi-state system, is completely rewritten. It now contains four chapters on quantum Brownian motion in a cosine potential, multi-state dynamics, duality symmetry, and tunneling of charge through an impurity in a quantum wire. Many new results available only very recently are presented. The about 460 references are suggestions for additional reading on particular subjects and are not intended as a comprehensive bibliography.

Stuttgart
December 1998   *Ulrich Weiss*

Preface to the First Edition

This book is an outgrowth of a series of lectures which I taught at the ICTP at Trieste and at the University of Stuttgart during the spring and summer of 1991. The purpose of my lectures was to present the approaches and techniques that accurately treat quantum processes in the presence of frictional influences.

The problem of *open* quantum systems has been around since the beginnings of quantum mechanics. Important contributions to this general area have been made by researchers working in fields as diverse as solid-state physics, chemical physics, biophysics, quantum measurement theory, quantum optics, nuclear and particle physics. Often, there has been used, and still is used, a language well known in one context or one field, yet sufficiently different from others that it is not altogether easy to make out the connection. Here, I offer a collection of ideas and examples rather than a comprehensive review of the topic and the history.

The central theme is the space-time functional integral or path integral formulation of quantum theory. This approach is particularly well suited for treating the quantum generalization of friction. Here we are faced to understand the behavior of a system with few quantal degrees of freedom coupled to a thermal reservoir. After integrating out the bath while keeping the system's coordinates fixed we get the influence functional describing the influence of the many bath degrees of freedom on the few relevant ones. This leads to an effective action weighting the paths of the open system in the functional integral description. Indeed, if one wishes to perform numerical computations on a rigorous level, there are no alternatives to this approach at present.

Path integration in condensed matter and chemical physics has become a growth industry in the last one or two decades. A newcomer to this thriving field may not yet be very familiar with the path integral method. Here, I do assume a knowledge of standard text book quantum mechanics and statistical mechanics augmented by a knowledge of Feynman's approach on a first introductory level. The books by Baym [1], Chandler [2], Feynman and Hibbs [3], and by Feynman [4] provide the elementary material in this regard. Further background and supplementary material on the path integral method are contained in the books by Schulman [5] and by Kleinert [6]. However, advanced mastery of these subjects is not necessary.

Some of the more sophisticated concepts, such as preparation functions, propagating functions, and correlation functions, are basic to the development as it is presented here. To cover this material at an introductory level, I make frequent use of simplified models. In this way, I can keep the mathematics relatively simple.

Many of the problems, methods, and ideas which are discussed here have become essential to the current understanding of quantum statistical mechanics. I have made a considerable effort to make the material largely self-contained. Thus, although the theoretical tools are not developed systematically and in its full beauty, the material

may be useful to many graduate students to become familiar with the field and learn the methods. For the most part, I refrain from just quoting results without explaining where they come from. With regard to citations, I have tried to give references to the historical development and also to provide a selection of the very recent important ones. But the list is surely not a comprehensive bibliography.

This book exists because of the physics I learned and enjoyed from the fertile collaboration with Hermann Grabert, Peter Hänggi, Gert-Ludwig Ingold, Peter Riseborough, and Maura Sassetti. I am particularly indebted to Maura who took time off her research to weed out points of confusion and who persistently encouraged me to finish this venture. I am also grateful to my students Reinhold Egger, Manfried Milch, Jürgen Stockburger, and Dietmar Weinmann for helpful comments concerning the presentation of many subjects discussed here and for preparing the figures.

In writing this book, I have benefited from the discussion with many companions; in particular Uli Eckern, Enrico Galleani d'Agliano, Anthony J. Leggett, Hajo Leschke, Franco Napoli, Albert Schmid, Gerd Schön, Larry Schulman, Peter Talkner, Valerio Tognetti, Andrei Zaikin, and Wilhelm Zwerger, who helped me in increasing my understanding of many of the subjects which are discussed here.

It is a pleasure to thank my teacher, colleague, and friend Wolfgang Weidlich for many fruitful discussions over the years.

Finally, and most importantly, I am deeply grateful to my wife Christel and my children Ulrike, Jan, and Meike for their infinite patience and omnipresent sympathy.

Stuttgart
October 1992   *Ulrich Weiss*

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