Preface to the Second Edition

Since the first edition of this book, a number of significant developments took place regarding both the experimental studies of polarization, alignment, and orientation phenomena and the theoretical treatment, especially concerning numerical calculations. Even though we are not aiming for a comprehensive review, it seemed appropriate to prepare a second edition of this book in order to highlight some of these developments.

Rather than changing much of the original text (except for fixing a few minor printing mistakes), we decided to provide updates via additional (sub)sections throughout the book. The most significant change is the splitting of what used to be Chap. 11, *Related Topics and Applications*. Photo-driven processes now have their own chapter, since this field almost exploded with the rapid development of new-generation light sources such as free-electron lasers. Furthermore, we added experimental developments such as the magnetic angle changer and the reaction microscope, as well as new experimental benchmark data that were obtained with these improved detection techniques. Regarding the numerical treatment, much progress has been made in developing convergent close-coupling techniques, either formulated in momentum space (CCC) or in coordinate space using the R-matrix with pseudo-states (RMPS) approach. Furthermore, rapid advances in computational resources (hardware and software) have made explicitly time-dependent formulations a competitive technique even in some steady-state arrangements. They are, of course, necessary to describe short-pulse intense laser-matter interactions.

Note that there are three other books in this Springer Series that deal with topics also covered in the present book, namely:

1. *Plasma Polarization Spectroscopy* by T. Fujimoto and A. Iwamae (2008);
2. *Angle and Spin Resolved Auger Emission* by B. Lohmann (2009);
3. *Perfect/Complete Scattering Experiments* by H. Kleinpoppen, A.N. Grum-Grzhimailo, and B. Lohmann (2009).

We have tried to minimize the overlap with the above books and essentially referred to the first two in our short subsections on Auger electrons and plasma polarization spectroscopy. Regarding perfect/complete experiments, especially for electron collisions, our treatment is more extensive, especially regarding the “natural” coordinate system, detailed cases studies, and the numerous examples presented in Part II of the book.

Finally, instead of providing a CD with supplemental material as in the first edition, the charge cloud movies and historical papers are now made available through electronic depositories at 10.1007/978-3-319-55216-3_7, 10.1007/978-3-319-55216-3_8, 10.1007/978-3-319-55216-3_10, and 10.1007/978-3-319-55216-3_13.

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Preface to the First Edition

Since the early work of Étienne Malus, polarization studies have played an increasingly important role in science as a tool for understanding natural phenomena. In the field of atomic collision physics, the polarization of photons and electrons emerging from the collision zone is in many cases intimately related to the dynamical evolution of the collision complex. Therefore, a quantitative understanding of the origin of the observed polarization and the development of appropriate concepts for describing the emission process have been a central goal of theoretical and experimental studies since the early days of collision studies in the 1920s. The idea of a "perfect" or "complete scattering experiment" introduced in the late 1960s, as well as the concept of "alignment" and "orientation," was of crucial importance for the further advancement of the field. The latter allowed for a proper disentanglement of dynamical and geometrical features and aimed at describing the shape of the collisionally excited atomic electron cloud and its intrinsic currents.

Since then, systematic and coordinated theoretical and experimental investigations have gradually led to a very satisfactory situation concerning the understanding and accurate description of many fundamental electronic and atomic collision processes in Nature. Thus, at the end of the 1990s, atomic collision theory has developed into a mature state in which collision-induced polarization phenomena for a few benchmark systems have been measured and predicted with an unprecedented accuracy and degree of detail over a wide range of impact energies. At the same time, these studies often reveal a very detailed and direct picture of the collision dynamics. Hence, the experimental methods, the general framework, and the numerical approaches have now been developed to a level that provides an excellent starting point for the study of even more complex collision problems. Apart from being of high intrinsic interest for the community of atomic physicists, this gain in understanding is also expected to be useful for applications in neighboring fields of science, such as surface, solid state, and nuclear physics, astronomy, and the physics of lasers, plasmas, and planetary atmospheres.

Based upon current knowledge, the present book aims at introducing the non-expert reader into this field without having to go through the individual papers or the comprehensive, technical reviews in the literature. With this in mind, Part I of the book describes polarized light (Chap. 2) and polarized electrons (Chap. 3), experimental and theoretical methods for scattering studies (Chap. 4), the density matrix formalism as a convenient tool for the theory of measurement (Chap. 5), and basic numerical methods (Chap. 6) that are widely used in calculations supporting ongoing experiments. This part of the book is aimed primarily toward graduate students in physics and has been used as a basis for graduate courses in atomic physics. Therefore, some chapters are supplemented with suggested problems.

Part II presents in a systematic way a series of case studies selected with the aim of illustrating applications of the framework developed in Part I to fundamental atomic collision processes for electronic (Chap. 7) and heavy-particle (Chap. 8) impact. No attempt is being made toward a complete coverage, but rather to "tell a story" concentrating on a few benchmark systems. Chapters 9 and 10 on propensity rules and particle-impact ionization, respectively, address further topics of intense current research. These sections, together with Chap. 11 on selected applications of polarization studies in other areas of physics, indicate the potential of the formalism and its expected impact on future research. Hence, in addition to the graduate student reader mentioned above, this part is intended for active researchers in atomic collision physics who would like to place their own work in a broader perspective and to researchers in neighboring fields who want to evaluate the potential of applying polarization studies in their own field.

With the form of presentation chosen for this book, an uninitiated reader may be carried to the frontier of the field in a short time and with a relatively modest effort. On the other hand, the approach hides the long, fascinating, and sometimes tortuous development which, with numerous detours, has led to the present situation. Furthermore, it does not always give sufficient credit to the early pioneers on whose joint efforts this presentation rests. In particular, it hides the interesting and often very educational paths along which the critical concepts were developed. In an attempt to remedy this situation, we have selected for Part III some of the early, pathbreaking publications in this field from the period 1925–1975. Due to space limitations, a few sections from the longer papers have been omitted, and sometimes, short initial notes of the research results have been chosen instead of the longer follow-up publications that give more results and sometimes important details. Consequently, the book is accompanied by a CD-ROM that contains all the papers of Part III, as well as a few related publications. We have used these papers successfully as reading material in graduate student courses to give a flavor of what really happened when the principal ideas were born. Furthermore, the CD-ROM contains movies of theoretically predicted electron charge clouds and currents for some of the cases discussed in Part II.

Many people have helped us during the preparation of this book. We are particularly indebted to Gordon Drake for suggesting the book project as a follow-up to our contributions to the "Handbook on Atomic, Molecular, and Optical Physcis" and to Maria Taylor and Jenny Wolkowicki for administering the project with Springer-Verlag, to, Bill Baylis, Albert Crowe, Friedrich Hanne, Joachim Kessler, Mette Machholm, Bill McConkey, Andy Mikosza, Jim Williams, Dehong Yu, and

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