Preface

Progress in atomic physics has been so vigorous during the past decade that one is hard pressed to follow all the new developments. In the early 1990s the first atom interferometers opened a new field in which we have been able to use the wave nature of atoms to probe fundamental quantum mechanics questions as well as to make precision measurements. Coming fast on the heels of this development was the demonstration of Bose–Einstein condensation in dilute atomic vapors which intensified research interest in studying the wave nature of matter, especially in a domain in which "macroscopic" quantum effects (vortices, stimulated scattering of atomic beams) are visible.

At the same time there has been much progress in our understanding of the behavior of waves (notably electromagnetic) in complex media, both periodic and disordered. An obvious topic of speculation and probably of future research is whether any new insight or applications will develop if one examines the behavior of de Broglie waves in analogous situations.

Finally, our ability to manipulate atoms has allowed us not only to create macroscopically occupied quantum states but also to exercise fine control over the quantum states of a small number of atoms. This has advanced to the study of quantum entanglement and its relation to the theory of measurement and the theory of information. The 1990s have also seen an explosion of interest in an exciting potential application of this fine control: quantum computation and quantum cryptography.

Despite this bewildering variety of phenomena, we scientists must continually make attempts to synthesize and explain our progress both to our students, the researchers of tomorrow, and to the general public. Thus, the purpose of this school was to bring together some of the participants in the trends mentioned above and ask them to give synthetic and pedagogical lectures on these topics in the hope of setting the stage for the research of the next decade, in which a large number of the students at the school will surely participate. At this task the invited lecturers succeeded admirably, generally attending each others' lectures and commenting on them in their own. The students did their part as well by asking a lot of questions during the lectures, continuing the discussions in the lounge afterwards, and organizing sessions, devoted talks and posters. In addition, thanks to Bill Phillips, our school has contributed to informing the general public about some of our recent progress.

The first part of this volume is devoted to several aspects of Bose–Einstein condensation. Yvan Castin begins with a "simple" theoretical introduction, along with a discussion of experimental tests of the theory. Wolfgang Ketterle follows up with an extensive discussion of recent experiments and experimental techniques in this field. Finally Henk Stoof's contribution complements the approach of Yvan Castin with a field theoretic approach to a number of current problems. Steven Chu discusses atom interferometry, which has enabled a number of striking precision measurements in recent years. These techniques are also interesting because they are being reapplied to Bose–Einstein condensates instead of just to individual atoms. Unfortunately, Eric Cornell, who also gave a series of lectures on Bose–Einstein condensation, was unable to contribute a written manuscript.

The second part of the book contains some discussions of wave behavior in complex media. Bart van Tiggelen discusses wave propagation in disordered media with some special remarks directed toward the atomic matter wave community, and Dominique Delande discusses the problem of the quantum behavior of classically chaotic systems. Sajeev John contributed a set of lectures on photonic band gaps.

The third part of the book is devoted to the quantum manipulation of systems with few atoms, but which may be coupled to a large reservoir. Wojciech Zurek and Juan-Pablo Paz teamed up to discuss the problems of quantum coherence and decoherence and its relation to quantum information theory. These lectures had an interesting resonance with those of Dominique Delande on quantum chaos. Michel Brune then discusses recent experiments on decoherence and entanglement. Finally, Artur Ekert contributed some lectures on quantum information processing, and in particular on quantum computing.

We were fortunate to benefit from two visitors who gave seminars, Guillaume Labeyrie, who has contributed a short article to this volume, and to Bill Phillips. Bill Phillips also entertained us and the citizens of the town of Les Houches with a public lecture on the nature of absolute zero temperature. A standing-room-only crowd of more than 300 people came to see Bill dip balloons and flowers in liquid nitrogen and talk about laser cooling. Many thanks to Robert Romestain, who ferried the liquid nitrogen all the way from Grenoble.

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