Preface

The experimental realization of Bose–Einstein condensates (BECs) in 1995, in dilute atomic gases of ^{87}Rb and ^{23}Na, later honored with the Nobel Prize in Physics in 2001, was arguably one of the most important feats of the previous decade. The importance of this achievement is multi-faceted. Not only did it experimentally lead to the development and use of the newest and most sophisticated techniques for atomic cooling, trapping and imaging, but it also provided an excellent playground for comparison of theoretical predictions with experimental results. Not only did it pave the way for a deeper understanding of bosonic and fermionic behavior and of the crossover between the two, but it also led to fundamental advances in the study of coherent structures and patterns, including those of vortices and vortex lattices that were the theme of the Nobel Prize in Physics in 2003. Addressing and assessing this last impact aspect was one of the primary motivations of the present book.

A number of distinguished colleagues have succinctly described the "revolution" that was brought to the area of atomic physics by the realization of Bose–Einstein condensation. Nevertheless, one of the aspects that has perhaps been touched upon less is that of the cross-pollination that has emerged in the field of BECs with the fields of wave physics, nonlinear optics and nonlinear science more generally. The interface between these diverse areas of Physics has, perhaps primarily, been formulated by the presence of a very good mean-field model that can capture the experimental phenomenology not just qualitatively but also quantitatively in the appropriate limits. This model is the so-called Gross–Pitaevskii equation which is a form of the famous Nonlinear Schrödinger equation. The latter equation had been previously studied extensively in connection to nonlinear phenomena in optics, plasma physics and fluid dynamics. However, the BEC setting presented a number of novel particularities and flexibilities, including, but not limited to, the presence of external potentials and the possibilities for manipulation of these potentials or of the effective nonlinearity and dimensionality of the model. These features have naturally posed a wide array of exciting challenges that, in turn, have spurred both experimental and theoretical developments at the cutting edge of nonlinear, atomic, and optical physics.

The idea for this book stemmed from the fact that in our own internal research excursions to this field, as well as in our interactions with our students and post-docs, we did not have a book to direct them to that addresses this interface: a book that covers this atomic physics theme, with a nonlinear wave dynamics bend and with references to other areas of physics where such notions arise. On the other hand, there are thousands of research papers and a tremendous amount of progress in this area, over the past 5–10 years. We felt that these would render such a book a valuable resource and a point of reference both for beginning, as well as for more seasoned researchers in this field. We decided that perhaps the best way to compile such a volume that would include a wide and diverse set of topics on nonlinear phenomena in BECs would be to invite a number of well-known experts to contribute a review each in their primary areas of focus within this wider theme. To make the relevant presentation more complete and to do justice to both the theoretical and the experimental aspects, we decided to partition each book part in two corresponding chapters. Our structuring of the table of contents of this volume was such as to try to touch upon the most important directions of this interface – admittedly, this is a selection that bears a personal flavor.

We were extremely lucky that our initial invitations and overall vision of this project were met with particular enthusiasm by a truly remarkable set of leading researchers in this field that kindly agreed to contribute. This book would simply not have materialized without their insightful, thorough and timely contributions, their professional and efficient coordination and their overall effort. We hope that the end result will be one that will be of value to a large number of researchers in this field, and will cover a significant gap in the literature of the subject. We also hope that it will serve as an educational resource for advanced students in Theoretical Physics, Experimental Physics and Applied Mathematics that are interested in this area.

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