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Preface

It is with great pleasure that I write this preface for Yvan Castin's eagerly awaited book on the physics of ultracold boson gases. Yvan was my student at the Kastler Brossel laboratory at the ENS, and I have followed his work throughout his distinguished career. The book he has just completed represents a synthesis of all the knowledge he has accumulated on a highly topical subject and also reflects the breakthroughs he himself has made. I am convinced that it will be a valuable resource for all researchers, both experimentalists and theoreticians, who today work on and with Bose-Einstein condensates in a large proportion of atomic physics laboratories.

Since Albert Einstein's seminal article in 1925, which generalized an idea of Bose, degenerate quantum boson gases have long remained in the realm of theory. The advent of laser-based atom cooling methods in the 1980s, which earned William Phillips, Steven Chu, and me the 1997 Nobel Prize, renewed research fields in atomic physics worldwide. Following an immense effort, a new revolution occurred in 1995 when the first gaseous Bose-Einstein condensates were produced in the laboratory, with cold atoms, in the group of Eric Cornell and Carl Wieman at JILA, and then in that of Wolfgang Ketterle at MIT—all three of whom were also Nobel laureates in 2001. Many teams quickly seized on these spectacular results. This new state of matter has the surprising property of being characterized by a unique wave function for a macroscopic fraction of the atoms in the gas. It serves either as a tool for important applications or as a subject of theoretical studies in the highly diverse configurations where condensates can be produced: partial condensation, reduced dimensionality, gas excited in a trap or in a potential box, etc.

Yvan Castin himself contributed to enriching the theoretical palette relating to condensate dynamics, with the effect of non-condensed modes and finite sample size as the guiding principle of his research. The famous nonlinear Gross-Pitayevski Schrödinger equation describing the condensate mode was no longer sufficient to explain all the observed phenomena. New theories had to be developed. Our laboratory is particularly grateful to Yvan for providing the explanation for the formation of the vortices observed by Jean Dalibard's team

when a (laser!) spoon stirs the condensate, as shown in the cover image of this book: it is, in fact, very tangible proof of the superfluid nature of the medium.

This book is an in-depth review of the subject. Without attempting to answer all the questions raised by each specific experiment, it is at a high conceptual level that allows it to address problems that are still largely open, such as the coherence time of a condensate at non-zero temperature, or the preparation of quantum states useful in metrology through spin squeezing.

Thank you and congratulations to Yvan Castin for taking on the challenge of passing on his knowledge, in a form that is as comprehensive as it is educational, to the younger generations who are responsible for the expected progress.

Paris, May 2024

Claude Cohen-Tannoudji