Quantum computers, though not yet available on the market, will revolutionize the future of information processing. Quantum computers for special purposes like quantum simulators are already within reach. The physics of ultracold atoms, ions, and molecules offer unprecedented possibilities of control of quantum many-body systems and novel possibilities of applications to quantum information processing and quantum metrology. Particularly fascinating is the possibility of using ultracold atoms in lattices to simulate condensed matter or even high energy physics.

This book provides a complete and comprehensive overview of ultracold lattice gases as quantum simulators. It opens up an interdisciplinary field involving atomic, molecular and optical physics, quantum optics, quantum information, condensed matter, and high energy physics. The book includes some introductory chapters on basic concepts and methods, and then focuses on the physics of spinor, dipolar, disordered, and frustrated lattice gases. It reviews in detail the physics of artificial lattice gauge fields with ultracold gases. The last part of the book covers simulators of quantum computers. After a brief course in quantum information theory, the implementations of quantum computation with ultracold gases are discussed, as well as our current understanding of condensed matter from a quantum information perspective.

Maciej Lewenstein is an ICREA professor at the Institut de Ciències Fotòniques in Castelldefels, Spain, where he leads the quantum optics theory group.

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‘Cold atoms and molecules is a hot topic at the interface between atomic physics, condensed matter physics and quantum information. This book belongs on the desk of every graduate student and postdoc in this field, and provides an excellent monograph for the experienced researcher who wants to get an overview of the various aspects of strongly interacting quantum degenerate gases.’

Peter Zoller, Institute for Theoretical Physics, University of Innsbruck, Austria

‘This masterpiece is a unique opportunity to learn about the frontiers of quantum many-body physics, and how they can be explored with ultracold atoms in optical lattices. Some of the most talented theorists in the field guide the readers through the fascinating interplay of atomic, optical and condensed-matter physics, where old and new quantum many-body phenomena appear.’

Giovanni Modugno, Università di Firenze, Italy

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Simulating Quantum Many-Body Systems