Preface

This book represents the lecture notes for the course I gave at the Imperial College London for three years in a row between 2001 and 2004. I have edited the notes to make them more suitable for publication, but at the same time I have tried to change as little as possible in order to stay close to the spirit and style of the lectures which were an optional course for third and fourth year physics undergraduate studies. The course consisted of 26 lectures and three extra special topic lectures. The extra topics were intended to cover very recent advances in and applications of quantum optics. I focused on experiments on Rabi oscillations in cavity QED, on the achievement of atomic Bose–Einstein condensation and on quantum teleportation. These recent advancements — some of which have resulted in several recent Nobel prizes — show that quantum optics is a very exciting and important subject to learn.

The reader will see that in addition to the modern application, I have tried to present many topics in an original way, always keeping in mind modern developments and understanding. Of course, there are many standard derivations in my notes that can also be found in many other textbooks, some of them covered in much more detail in these other books. I pretend neither to have written a detailed nor a complete exposition of the subject. The choice of topics reflects very much my personal bias, my research interests and preferences. For example, I discuss the topic of Maxwell's demon and how the wave and particle nature of light can possibly be used to violate the second law of thermodynamics. I also discuss the notion of phase in quantum mechanics, the difference between dynamical and geometrical phases, as well as some very basic ideas behind the gauge principle and how electromagnetism can be derived from the Schrödinger equation. These additional topics, not traditionally covered by conventional texts, were intended to show that quantum optics is not an isolated subject, but that it is very intimately

related to other areas of physics. They were also intended to break the monotony of the routine of only going through the, frequently tedious, background material. I wanted to show my students how exciting and lively the subject can be even at this introductory level, and that they can actively participate in it from the very start.

The order in which the notes are written is sometimes historical, sometimes didactic, frequently neither. More frequently than not they are written in the order of increasing complexity — which does not always coincide with the historical development. The logic of the course was to present different levels of our understanding of light — and quantum optics is the most sophisticated such understanding we have — through its interaction with matter. Loosely speaking, there are four levels in the notes: the classical, the old quantum, the semi-classical and the fully quantum level. I motivate some of the more traditional topics with examples that are both technologically and conceptually challenging. For example, I introduce the Mach–Zehnder interferometer with single photons at the very start to show not only that photons behave like particles and waves at the same time, but also that this can be exploited to perform operations that are unimaginable in classical physics — such as the interaction-free measurement. I have included five sets of problems and solutions. These are taken mainly from my three exam papers and are meant for the students to test their understanding of the presented material. Problem solving is, as always, crucial for understanding of any subject.

The notes end at the point where the field theory proper should begin. One could say — perhaps somewhat misleadingly — that quantum optics is the lowest order approximation to the full quantum field theory. From my experience in teaching, it seems that learning quantum optics first is a much better way of understanding the field theory than the usual second quantization formalism.

Finally, I had great fun working with students at Imperial College London, who not only taught me the subject, but also taught me how to teach. I hope you enjoy reading the notes as much as I enjoyed teaching the course!

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