PHY

国外物理名著系列 1

（影印版）

Quantum Optics

Including Noise Reduction, Trapped Ions, Quantum Trajectories, and Decoherence

量子光学

——降噪，囚禁离子，量子轨道和退相干

M. Orszag

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《国外物理名著系列》(影印版)专家委员会名单

(按姓氏笔画排序)

国外物理名著(影印版)系列序言

对于国内的物理学工作者和青年学生来讲，研读国外优秀的物理学著作是系统掌握物理学知识的一个重要手段。但是，在国内并不能及时、方便地买到国外的图书，且国外图书不菲的价格往往令国内的读者却步，因此，把国外的优秀物理原著引进到国内，让国内的读者能够方便地以较低的价格购买是一项意义深远的工作，将有助于国内物理学工作者和青年学生掌握国际物理学的前沿知识，进而推动我国物理学科研和教学的发展。

为了满足国内读者对国外优秀物理学著作的需求，科学出版社启动了引进国外优秀著作的工作，出版社的这一举措得到了国内物理学界的积极响应和支持，很快成立了专家委员会，开展了选题的推荐和筛选工作，在出版社初选的书单基础上确定了第一批引进的项目，这些图书几乎涉及了近代物理学的所有领域，既有阐述学科基本理论的经典名著，也有反映某一学科专题前沿的专著。在选择图书时，专家委员会遵循了以下原则：基础理论方面的图书强调“经典”，选择了那些经得起时间检验、对物理学的发展产生重要影响、现在还不“过时”的著作（如：狄拉克的《量子力学原理》）。反映物理学某一领域进展的著作强调“前沿”和“热点”，根据国内物理学研究发展的实际情况，选择了能够体现相关学科最新进展，对有关方向的科研人员和研究生有重要参考价值的图书。这些图书都是最新版的，多数图书都是2000年以后出版的，还有相当一部分是2006年出版的新书。因此，这套丛书具有权威性、前瞻性和应用性强的特点。由于国外出版社的要求，科学出版社对部分图书进行了少量的翻译和注释（主要是目录标题和练习题），但这并不会影响图书“原汁原味”的感觉，可能还会方便国内读者的阅读和理解。

“他山之石，可以攻玉”，希望这套丛书的出版能够为国内物理学工作者和青年学生的工作和学习提供参考，也希望国内更多专家参与到这一工作中来，推荐更多的好书。

杨国桢

中国科学院院士

中国物理学会理事长

2007年3月20日

To all those who gave me their support and wisdom.

My parents

Ladislao Orszag (1911–1984)

Isabel Posa (1908–1999)

and

Martita.

Preface

This graduate text originated from lectures given by the author at the Universidad Católica de Chile in Santiago, as well as at the University of New Mexico. Also, material has been drawn from short summer courses given in Rio de Janeiro and Caracas.

Chapter 1 is devoted to some basic ideas of the interaction of radiation and matter, starting from Einstein's ideas of emission and absorption, and ending with elementary laser theory.

The quantum mechanical description of the atom–radiation interaction is dealt with in Chap. 2, and includes Rabi's oscillations and Bloch's equations.

Chapter 3 contains the basic quantization of the electromagnetic field, while Chaps. 4, 5 and 6 study special states of the electromagnetic field and the quantum theory of coherence.

The Jaynes–Cummings model, which describes in a fully quantized manner, the atom–radiation interaction, is studied in Chap. 8, along with the phenomena of collapse and revival. We also introduce the dressed state description, which is useful when studying resonance fluorescence (Chap. 10).

Real physical systems are open, that is, one must always consider dissipative mechanisms, including electromagnetic losses in cavity walls or atomic decay. All these effects can be considered in great detail, by studying system–reservoir interactions, leading to the master and Fokker–Planck equations. These reservoirs can also be phase dependent, an effect that can modify the decay rate of an atom (Chap. 9). As we mentioned before, Chap. 10 is entirely devoted to resonance fluorescence, and the study and observation of photon antibunching.

The invention of the laser, in the 1960s, opened up a new area of research, baptized quantum optics. This discovery spurred the growth of new research fields such as non-linear optics and non-linear spectroscopy. First the semiclassical theory, and then the quantum theory of the laser was well developed by the late 1960s. The quantum theory of the laser, based on the master equation and the Langevin equation approach, is extensively treated in Chaps. 11 and 12, respectively. We have also added some more recent material, including the micromaser and the effect of pump statistics, as a form of noise reduction scheme. Although pump statistics did not play any role in the original laser theory, recent experiments and theoretical calculations have shown that one could reduce considerably the photon number fluctuations if one is careful enough in pumping the atoms in an orderly way.

We further study quantum noise reduction in correlated emission lasers and the generation of squeezed states, typically from a parametric oscillator. These subjects are studied in Chaps. 13 and 14 respectively. In Chap. 14 we also introduce the input–output theory, which is very appropriate for describing the parametric oscillator and other non-linear optical systems.

Quantum phase, which started with Dirac, is a controversial subject, even today (Chap. 15). Most of the time optical experiments deal with direct or indirect measurement of a phase. For this reason, I felt it was important to include it in this book, even if it may not be a mature subject.

The last five chapters deal with more recent topics in quantum and atom optics. The Monte Carlo method and the stochastic Schrödinger equation (Chap. 16) are recent tools that have been used to attack optical problems with losses. Theoretically, it takes a different point of view from the more traditional way via the master or Fokker–Planck equations, and it is convenient for practical simulations.

Measurements in optics, and physics in general, play a central role. This was recognized early in the history of quantum mechanics. We introduce the reader to the notions of quantum standard limits and quantum non-demolition measurements (Chap. 18). A detailed example is studied in connection with the QND measurement of the photon number in a cavity. Continuous measurements are also studied. A related subject, decoherence (Chap. 20), is quite relevant for quantum computing. This intriguing phenomenon is connected with dissipation and measurement.

Finally, although a bit outside the scope of quantum optics, we have included the topics of atom optics (Chap. 17) and trapped ions (Chap. 19). These are fast-growing areas of research.

Over the years I have collaborated with many colleagues and students, who directly or indirectly contributed to this work; in particular: G.S. Agarwal, Claus Benkert, Janos Bergou, Wilhelm Becker, Luiz Davidovich, Mary Fuka, Mark Hillery, T. Kist, María Loreto Ladron de Guevara, Jack. K. McIver, Douglas Mundarain, L.M. Narducci, Ricardo Ramírez, Juan Carlos Retamal, Luis Roa, Jaime Röessler, Bernd Rohwedder, Carlos Saavedra, Wolfgang Schleich, Marlan O. Scully, D.F. Walls, Herbert Walther, K. Wodkiewicz, Nicim Zagury, F.X. Zhao, Sh.Y Zhu. I thank them all.

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Finally, last but not least, I would like to thank my wife Marta Montoya (Martita) for her love and constant support during this project.

Santiago, April 1999 *Miguel Orszag*

No te escapes
Ahora
Ma ayudarás. Un dedo,
una palabra,
un signo
tuyo
y cuando
dedos, signos, palabras
caminen y trabajen
algo
aparecerá en el aire inmóvil,
un
solidario sonido en la ventana,
una estrella en la terrible paz nocturna,
entonces
tu dormirás tranquilo,
tu vivirás tranquilo:
será parte
del sonido que acude a tu ventana,
de la luz que rompió la soledad.

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