Preface

Quantum descriptions of light propagation frequently exhibit a replacement of time by propagation distance. It seems to be natural since a propagation lasts some amount of time. The primary intention was to inform more fundamentally inclined, open-minded readers on this approach by this book. We have included also spatio-temporal descriptions of the electromagnetic field in linear and nonlinear optical media. We call some of these formalisms one dimensional (more exactly 1 + 1-dimensional), even though they comprise the time variable along with the position coordinate. These descriptions, however, are 3 + 1-dimensional in principle. The rapid development of applications of photonic band-gap structures and experiments on lasing in a disordered medium has directed us to pay attention even to these topics, which has influenced the style of the book, which becomes a very review of these streams.

This book has the following features. It reviews both macroscopic and microscopic theories of the electromagnetic field in dielectrics. It takes into account parametric down-conversion experiments. It covers results on nonlinear optical couplers. It includes optical imaging with nonclassical light. It expounds basics of quasimode theory. It respects success of the Green-function approach in describing optical field at dielectric devices, left-handed materials and the Casimir effect for some geometries. It refers to quantization in waveguides, photonic crystals, disordered media, and propagation in strongly scattering media, incoherent and coherent random lasers, and important problems in optical resonators including chaotic cavities. In our opinion it is appropriate to do something more than only formal comparison of various approaches in the future, even though the reader will already have formed an idea of their scope.

The simplest approach with one variable (time or propagation distance) and with several frequencies has proven its vitality in the development of the quantum information theory and the quantum computation. At present there exist even books devoted to these fields: Alber, G., Beth, T., Horodecki, M., Horodecki, P., Horodecki, R., Rötteler, M., Weinfurter, H., Werner, R., and Zeilinger, A. (2001), *Quantum Information: An Introduction to Basic Theoretical Concepts and Experiments*, Springer-Verlag, Berlin; Nielsen, Michael A. and Chuang, Isaac L. (2000), *Quantum Computation and Quantum Information*, Cambridge University Press, Cambridge.

The fundamental problem of light propagation in dielectric media is connected with the role of nonclassical light in applications and has been pursued intensively in quantum optics since about 1984. In the present book we review spatio-temporal descriptions of the electromagnetic field in linear and nonlinear dielectric media applying macroscopic and microscopic theories. We mainly pay attention to canonical quantum descriptions of light propagation in a nonlinear dispersionless dielectric medium and linear and nonlinear dispersive dielectric media. These descriptions are regularly simplified by a transition to the one-dimensional propagation, which is illustrated also by descriptions of some optical processes.

Quantum theories of light propagation in optical media are generalized from dielectric media to magnetodielectrics. Classical and nonclassical properties of radiation propagating through left-handed media will be presented. The theory is utilized for the quantum electrodynamical effects to be determined in periodic dielectric structures which are known to be a basis of new schemes for lasing and a control of light field state. Quantum descriptions of random lasers are provided.

It is an interesting question, to what extent the topic of this book overlaps with the condensed-matter theory. Restricting ourselves to optical devices, we cannot exclude such overlap in principle, because many of them are made of condensed matters. The condensed-matter theory, however, is devoted mainly to problems of conductors and semi-conductors. Photonic crystals can be studied similarly as ordinary electronic crystals, even though for instance the conductivity is replaced by the transmissivity. This does not mean any thematic overlap.

Texts on quantum optics have so far based the spatio-temporal description on the quantization of the electromagnetic field in a free space in the hope that differences from the field in a medium are negligible or can be easily included in other ways. A rare exception was for instance the text Vogel, W. and Welsch, D.-G. (1994), *Lectures on Quantum Optics*, Akademie Verlag, Berlin, where a choice of a suitable approach, albeit a selection of one of possibilities, was declared.

The book will be useful to research workers in the field of general optics, quantum optics and electronics, optoelectronics, and nonlinear optics, as well as to students of physics, optics, optoelectronics, photonics, and optical engineering.

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