Fundamentals of Photonic Crystal Guiding

If you're looking to understand photonic crystals, this systematic, rigorous, and pedagogical introduction is a must. Here you'll find intuitive analytical and semi-analytical models applied to complex and practically relevant photonic crystal structures. You will also be shown how to use various analytical methods borrowed from quantum mechanics, such as perturbation theory, asymptotic analysis, and group theory, to investigate many of the limiting properties of photonic crystals, which are otherwise difficult to rationalize using only numerical simulations.

An introductory review of nonlinear guiding in photonic lattices is also presented, as are the fabrication and application of photonic crystals. In addition, end-of-chapter exercise problems with detailed analytical and numerical solutions allow you to monitor your understanding of the material presented. This accessible text is ideal for researchers and graduate students studying photonic crystals in departments of electrical engineering, physics, applied physics, and mathematics.

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M. Skorobogatiy dedicates this book to his family. He thanks his parents Alexander and Tetyana for never-ceasing support, encouragement, and participation in all his endeavors. He also thanks his wife Olga, his children, Alexander junior and Anastasia, and his parents for their unconditional love.

J. Yang dedicates this book to his family.

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Preface

The field of photonic crystals (aka periodic photonic structures) is experiencing an unprecedented growth due to the dramatic ways in which such structures can control, modify, and harvest the flow of light.

The idea of writing this book came to M. Skorobogatiy when he was developing an introductory course on photonic crystals at the Ecole Polytechnique de Montréal/University of Montréal. The field of photonic crystals, being heavily dependent on numerical simulations, is somewhat challenging to introduce without sacrificing the qualitative understanding of the underlying physics. On the other hand, exactly solvable models, where the relation between physics and quantitative results is most transparent, only exist for photonic crystals of trivial geometries. The challenge, therefore, was to develop a presentational approach that would maximally use intuitive analytical and semi-analytical models, while applying them to complex and practically relevant photonic crystal structures.

We would like to note that the main purpose of this book is not to present the latest advancements in the field of photonic crystals, but rather to give a systematic, logical, and pedagogical introduction to this vibrant field. The text is largely aimed at students and researchers who want to acquire a rigorous, while intuitive, mathematical introduction into the subject of guided modes in photonic crystals and photonic crystal waveguides. The text, therefore, favors analysis of analytically or semi-analytically solvable problems over pure numerical modeling. We believe that this is a more didactical approach when trying to introduce a novice into a new field. To further stimulate understanding of the book content, we suggest many exercise problems of physical relevance that can be solved analytically.

In the course of the book we extensively use the analogy between the Hamiltonian formulation of Maxwell's equations and the Hamiltonian formulation of quantum mechanics. We present both frequency and propagation-constant based Hamiltonian formulations of Maxwell's equations. The latter is particularly useful for analyzing photonic crystal-based linear and nonlinear waveguides and fibers. This approach allows us to use a well-developed machinery of quantum mechanical semi-analytical methods, such as perturbation theory, asymptotic analysis, and group theory, to investigate many of the limiting properties of photonic crystals, which are otherwise difficult to investigate based only on numerical simulations.

M. Skorobogatiy has contributed Chapters 2, 3, 4, 5, and 6 of this book, and J. Yang has contributed Chapter 8. Chapters 1 and 7 were co-authored by both authors.

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