Photonic Crystals and Light Localization in the 21st Century

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Photonic Crystals and Light Localization in the 21st Century

edited by

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PREFACE

This volume contains papers presented at the NATO Advanced Study Institute (ASI) *Photonic Crystals and Light Localization* held at the Creta Maris Hotel in Limin Hersonissou, Crete, June 18-30, 2000.

Photonic crystals offer unique ways to tailor light and the propagation of electromagnetic waves (EM). In analogy to electrons in a crystal, EM waves propagating in a structure with a periodically modulated dielectric constant are organized into photonic bands, separated by gaps where propagating states are forbidden. There have been proposals for novel applications of these photonic band gap (PBG) crystals, with operating frequencies ranging from microwave to the optical regime, that include zero-threshold lasers, low-loss resonators and cavities, and efficient microwave antennas. Spontaneous emission, suppressed for photons in the photonic band gap, offers novel approaches to manipulate the EM field and create high-efficiency light-emitting structures. Innovative ways to manipulate light can have a profound influence on science and technology.

The objectives of this NATO-ASI were (i) to assess the state-of-the-art in experimental and theoretical studies of photonic crystals, light localization, and random lasers; (ii) to discuss how such structures can be fabricated to improve technologies in different areas of physics and engineering; and (iii) to identify problems and set goals for further research. This was accomplished by the excellent presentations given by the lecturers and invited speakers, who paid special attention to the tutorial aspects of their contributions. The location of the NATO-ASI was a perfect and idyllic setting, which allowed the participants to develop scientific interactions and friendships. All objectives were met in the ASI and three areas within the field of photonic crystals were identified as the most promising and hope to receive considerable attention within the next few years.

The first area of effort is in materials fabrication. This involves the creation of high quality, low loss, periodic dielectric structures either in 3D or 2D, especially on the optical scale. However, optical photonic crystals may be best fabricated from self-organizing materials and techniques, than with conventional techniques used in the semiconductor industry.

The second area of consideration is applications and spin offs, which may have technological and economic importance. Several contributors presented possible applications of PBGs in microwave and optical regimes. Microwave mirrors, directional antennas, resonators (especially for the 2 GHz region), filters, switches, waveguides, Y splitters, and resonant microcavities were discussed. It was also pointed out that 2D photonic crystals, with a waveguide confinement in the perpendicular direction, might yield much richer structures and designs for optical applications.

Finally, the third area is the studies of fundamentally new physical phenomena in condensed matter physics and quantum optics associated with localization, random lasers, and photonic band gaps.

This book compiles the lectures presented at the *Photonic Crystals and Light Localization* NATO ASI meeting and presents an excellent review of the recent developments of this rapidly expanding field. The lectures cover theoretical, experimental, and the application aspects of photonic crystals, light localization, and random lasers. This collection of papers is roughly balanced between theory and experiment. It contains chapters that present the latest research results appropriate of an advanced research workshop, as well as results that review a particular field, with the goal of providing the reader with a sufficient overview and extensive references for a more detailed study.

The book is divided into eight chapters representing the various topics discussed at the ASI. Chapter I gives a historical overview of the PBG field, including acoustic and elastic PBGs. Chapter II provides a detailed experimental review of all the different techniques in fabricating photonic crystals in the infrared and optical wavelengths. Some applications to optoelectronic devices are presented in this chapter. Chapter III provides an up-to-date review of the experimental efforts in fabricating photonic crystals by self-organization. Chapter IV provides a detailed review of the potential application of photonic crystals, with specific examples in both the millimeter and optical regime. Chapter V covers the theoretical and experimental developments of metallic photonic crystal structures. Left-handed materials are discussed in this chapter. Chapter VI provides a detailed review of random lasers, which are disordered systems that both scatter and amplify light. Chapter VII provides an excellent review of the localization of light field. Finally, Chapter VIII covers some extra work on photonic crystals and nonlinearities. We hope this book will not only prove interesting and stimulating to researchers active in the PBG field, but also serve as a useful reference to non-specialists, because of the introductory lectures.

The advanced study institute was made possible through the generous support of the NATO Scientific Affairs Division, Brussels, Belgium and the Ames Laboratory, operated by the U.S. Department of Energy by Iowa State University under Contract No. W-7405-Eng-82. Support from University of Crete, FORTH, Greek General Secretariat of Research and Technology, the European Office of the U.S. Army Research Office, and NSF is also acknowledged. I would like to thank the organizing committee, E. N. Economou, S. John, and A. Lagendijk for their valuable help on the organization of the program and the workshop. I would like to express my appreciation to Rebecca Shivvers, who prepared the conference materials and edited the manuscripts for this book. Finally, I wish to express my deepest appreciation to all the participants for making this a lively and enjoyable conference.

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