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Makoto Naruse
Editor

# Nanophotonic Information Physics

## Nanointelligence and Nanophotonic Computing

Springer

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# Preface

This book contains nine review articles about nanophotonic information physics—with the subtitle nanointelligence and nanophotonic computing—and is the first publication of its kind.

Optical science and technologies have been experiencing tremendous advancements in recent years, especially at scales below the wavelength of light. Technological enablers have been cultivated both in top-down approaches such as nanoscale-precision lithography, and bottom-up ones, such as DNA-based self-assembly. The fundamental physical processes of light–matter interactions, such as energy transfer via near-field interactions, among others, have been extensively studied from the viewpoint of the basic science and enabling technologies of nanophotonics.

From an information standpoint, on the other hand, novel architectures should be considered so that we can fully utilize and benefit from the potential of the unique physical processes made possible by nanophotonics. There are plenty of degrees-of-freedom on the nanoscale, and a wide variety of physical processes and technologies exist. A comprehensive view covering diverse disciplines, including physics, materials, devices, systems, information, and architectures, is vitally important and will push the frontiers of physical and information sciences and technologies.

At the same time, such interdisciplinary and basic research areas that cover both physics and information—or real-world and abstract functions—will pave the way to gain fundamental insights and critical knowledge for implementing novel applications of nanophotonics that will be of key importance in our lives and for wider society, both today and in the future; these include computing, information systems, network systems, sensing and imaging, healthcare and welfare, safety and security, the environment and energy.

Such a research concept is represented by the title of this book. The nine selected articles in this book are based on presentations given at the First International Workshop on Information Physics and Computing in Nano-scale Photonics (IPCN), held in Orleans, France, in September 2012. The workshop aimed to bring researchers together and stimulate strong interest at the intersection of nanophotonics, nanoelectronics, and information science and technologies, a goal that is also shared by this book. It should be emphasized that novel architectural ideas, concepts, and paradigms are discussed in each chapter, besides concrete technological realizations.

Chapter 1 (Naruse et al.) discusses information physics fundamentals for nanophotonics. Chapters 2 (Dwyer et al.), 3 (Tanida), and 4 (Ogura et al.) present the original concepts of the authors and some practical applications. The concepts described in these three chapters are all based on DNA and related self-assembly principles and technologies, but it should be remarked that a variety of system-level ideas and benefits result. Chapters 5 (Kasai et al.) and 6 (Kawahito et al.) are based on nanoelectronics with unique device architectures for computing and imaging applications. Chapter 7 (Tate et al.) discusses interfacing issues, and corresponding solutions, between the macro- and nano-scale worlds, which are of critical importance for nanophotonic systems. Chapter 8 (Tait et al.) discusses photonic neuromorphic signal processing and computing, including both its fundamental theoretical concerns and photonic realizations. Chapter 9 (Aono et al.) paves the way to new problem-solving and decision-making methods based on the spatiotemporal optical excitation transfer dynamics provided by optical near-field interactions.

Through these inter- and cross-disciplinary investigations covering optical, material, and information sciences, besides considering applications and architectures that will provide new value via state-of-the-art technologies, it is my sincere hope to convey the excitement and sense-of-wonder that emerges, and that researchers will harness the fruits of these investigations in creating a new research area that merges physical and information sciences and technologies.

I am deeply indebted to the committee members, speakers, and participants of the IPCN Workshop and its subsequent in-depth discussions, especially Dr. Y. Ogura (Osaka University) who served as the co-chair of the workshop, and Dr. M. Aono (Tokyo Institute of Technology) who greatly helped in the successful organization of the workshop. Also, I would like to thank Dr. J. Tanida (Osaka University) for his encouragement and discussions throughout the course of the workshop and the preparation of this book. In addition, I sincerely thank Dr. M. Ohtsu (The University of Tokyo), who is the Editor-in-Chief of Nano-Optics and Nanophotonics, for his great encouragement of researchers in nanophotonics science and technology and for his support and suggestions for this book. Finally, I am grateful to Dr. C. Acheron of Springer–Verlag for his guidance and suggestions throughout the preparation of this book.

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