

Preface

The twenty-first century belongs to photonics and harnessing light is the key to life changing technologies, from energy to security, from biotechnology to low-cost precision manufacturing, from high-speed Internet to quantum-level information processing. Many important industries, ranging from integrated-circuit manufacturing, lighting, health care and life sciences, to the space, defence and automotive sectors, rely on the same fundamental mastery of light. Future technologies will demand a steep increase in photonic integration and energy efficiency, far surpassing that of bulk optical components, current silicon photonics, and even innovative plasmonic circuits. Such level of integration can be achieved by embedding the data processing and waveguiding functionalities at the level of the material rather than the chip, and the only possible solution to meet these challenges is to employ the recently emerged concept of metamaterials.

Metamaterials are artificial electromagnetic media structured on the subwavelength scale; they were initially suggested for negative refractive index and superlensing applications, but very soon they became a paradigm for engineering electromagnetic space and controlling the propagation of waves by means of transformation optics. The research agenda is now focusing on the realization of a new generation of metadevices, defined as metamaterial-based devices and structures with novel and useful functionalities achieved by structuring of functional matter on the subwavelength scale.

The fields of metamaterials and metadevices opened technologically important capabilities ranging from subwavelength focusing to unique abilities for controlling electromagnetic waves, by engineering subwavelength structured materials. Research on metamaterials emerged as a new area of physics and engineering, and it is now attracting rapidly growing interest worldwide. Metamaterials not only offer novel possibilities for practical applications and devices but also display unexplored and intriguing properties that challenge fundamental physical concepts. The main hindrance to the use of metamaterials in real-life applications is their absorption of electromagnetic waves and narrow frequency band of operation. The creation of nonlinear, tunable and active metamaterials will solve these problems and will lead to applications.

In particular, nonlinear phenomena are essential for almost all the areas of modern physics, ranging from quantum optics to electronic engineering, and they address a span of questions from fundamental theoretical research to practical engineering applications. Electronics utilizes the nonlinear effects offered by semiconductors through numerous devices. In optics, where nonlinearity originates from the weakly nonlinear atomic response, the key concerns were always related to the relatively high power required to observe useful effects; while electronics, capable of handling strongly nonlinear responses, is limited in speed.

Not surprisingly, the study of nonlinear effects attracted significant attention within the metamaterials research, which has flourished over the past decade. Metamaterials are artificial structures where specific engineered elements play the role of atoms on a macroscopic scale. By offering tremendous opportunities in designing and combining material properties, often reaching phenomena not available in nature, metamaterials are particularly suited to the introduction of nonlinearity. The advantages of the metamaterial paradigm will ensure a remarkable impact on the whole field of nonlinear optics: providing novel solutions to classical problems, on the one hand, and offering new phenomena and applications, on the other.

The aim of this book is to present theoretical, numerical, and experimental expertise in the physics of advanced tunable, nonlinear and active metamaterials and metadevices in different frequency ranges, including microwaves, terahertz and optics, and thereby to unite the fundamental concepts of these different growing fields. More specifically, the book addresses the major methods for creating metamaterials and enabling their tunability, and it presents the latest results on nonlinear, tunable and active metamaterials which are expected to create the background for future optical metadevices with useful applications such as efficient frequency converters, power limiters and parametric amplifiers. In particular, the authors discuss approaches to dynamically manipulate electromagnetic metamaterials in all frequency ranges.

The authors of the chapters are leading experts in the field of metamaterials, they advance the fundamental physics of structured materials and facilitate key experimental observations of many effects predicted theoretically.

The book is aimed at an audience already familiar with the basics of electromagnetic wave propagation. Especially, we address young, advanced scientists as well as scientists in research groups with experimental as well as theoretical expertise. It will offer insights into the basic principles of metamaterial design, homogenization procedures, wave propagation, nonlinear phenomena as well as computational aspects and—most importantly—work out the common ground of these apparently different physical situations where the apparatus is to be applied.

In particular, the chapters collected in this book discuss the fundamental properties and demonstrate control of nonlinear waves and localized excitations, including nonlinear effects in left-handed transmission lines, magnetoelastic interactions, superconducting quantum metamaterials, tunable liquid-crystal-based structures and the possibility of novel nonlinear effects in metamaterial structures that exhibit an optically induced nonlinear magnetic response. Special attention is

paid to the interplay between nonlinear and linear modes, which result in a number of interesting resonant scattering and trapping effects, and active control of the metamaterial parameters. We are confident that the joint gathering of independent contributions of experimentalists and theorists from each sub-field will boost the implementation of ideas and experimental techniques in all fields of research.

A book like this that compiles contributions of different authors is as good as the authors' contributions. Therefore, we thank all authors for their excellent articles as well as their support to the editorial process.

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