

An Introduction To Metamaterials And Waves In Composites

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An Introduction To Metamaterials And Waves In Composites

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Metamaterial Electromagnetic Wave Absorbers Cambridge University Press

The rapid development of technology based on metamaterials coupled with the recent introduction of the transformation optics technique provides an unprecedented ability for device designers to manipulate and control the behavior of electromagnetic wave phenomena. Many of the early metamaterial designs, such as negative index materials and electromagnetic bandgap surfaces, were limited to operation only over a very narrow bandwidth. However, recent groundbreaking work reported by several international research groups on the development of broadband metamaterials has opened up the doors to an exciting frontier in the creation of new devices for applications ranging from radio frequencies to visible wavelengths. This book contains a collection of eight chapters that cover recent cutting-edge contributions to the theoretical, numerical, and experimental aspects of broadband metamaterials.

[Information Metamaterials](#) CRC Press

This book presents original findings on tunable microwave metamaterial structures, and describes the theoretical and practical issues involved in the design of metamaterial devices. Special emphasis is given to tunable elements and their advantages in terms of feeding network simplification. Different biasing schemes and feeding network topologies are presented, together with extensive prototype measurements and simulations. The book describes a novel, unique solution for beam steering and beam forming applications, and thus paves the way for the diffusion of new agile communication system components. At the same time, it provides readers with an outstanding and timely review of wave propagation in periodic structures, tunability of metamaterials and the technological constraints that need to be considered in the design of reconfigurable microwave components.

Introduction to Photonic and Phononic Crystals and Metamaterials Springer

In the last few decades, metamaterials have revolutionized the ways in which waves are controlled, and applied in physics and practical situations. The extraordinary properties of metamaterials, such as their locally resonant structure with deep subwavelength band gaps and their ranges of frequency where propagation is impossible, have opened the way to a host of applications that were previously unavailable. Acoustic metamaterials have been able to replace traditional treatments in several sectors, due to their better performance in targeted and tunable frequency ranges with strongly reduced dimensions. This is a training book composed of nine chapters written by experts in the field, giving a broad overview of acoustic metamaterials and their uses. The book is divided into three

parts, covering the state-of-the-art, the fundamentals and the real-life applications of acoustic metamaterials.

Theory and Applications World Scientific

Electromagnetic metamaterials-from fundamental physics to advanced engineering applications This book presents an original generalized transmission line approach associated with non-resonant structures that exhibit larger bandwidths, lower loss, and higher design flexibility. It is based on the novel concept of composite right/left-handed (CRLH) transmission line metamaterials (MMs), which has led to the development of novel guided-wave, radiated-wave, and refracted-wave devices and structures. The authors introduced this powerful new concept and are therefore able to offer readers deep insight into the fundamental physics needed to fully grasp the technology.

Moreover, they provide a host of practical engineering applications. The book begins with an introductory chapter that places resonant type and transmission line metamaterials in historical perspective. The next six chapters give readers a solid foundation in the fundamentals and practical applications: Fundamentals of LH MMs describes the fundamental physics and exotic properties of left-handed metamaterials TL Theory of MMs establishes the foundations of CRLH structures in three progressive steps: ideal transmission line, LC network, and real distributed structure Two-Dimensional MMs develops both a transmission matrix method and a transmission line method to address the problem of finite-size 2D metamaterials excited by arbitrary sources Guided-Wave Applications and Radiated-Wave Applications present a number of groundbreaking applications developed by the authors The Future of MMs sets forth an expert view on future challenges and prospects This engineering approach to metamaterials paves the way for a new generation of microwave and photonic devices and structures. It is recommended for electrical engineers, as well as physicists and optical engineers, with an interest in practical negative refractive index structures and materials.

Optical Metamaterials Cambridge University Press

Leading experts explore the exotic properties and exciting applications of electromagnetic metamaterials Metamaterials: Physics and Engineering Explorations gives readers a clearly written, richly illustrated introduction to the most recent research developments in the area of electromagnetic metamaterials. It explores the fundamental physics, the designs, and the engineering aspects, and points to a myriad of exciting potential applications. The editors, acknowledged leaders in the field of metamaterials, have invited a group of leading researchers to present both their own findings and the full array of state-of-the-art applications for antennas, waveguides, devices, and components. Following a brief overview of the history of artificial materials, the publication divides its coverage into two major classes of metamaterials. The first half of the publication examines effective media with single (SNG) and

double negative (DNG) properties; the second half examines electromagnetic band gap (EBG) structures. The book further divides each of these classes into their three-dimensional (3D volumetric) and two-dimensional (2D planar or surface) realizations. Examples of each type of metamaterial are presented, and their known and anticipated properties are reviewed. Collectively, *Metamaterials: Physics and Engineering Explorations* presents a review of recent research advances associated with a highly diverse set of electromagnetic metamaterials. Its multifaceted approach offers readers a combination of theoretical, numerical, and experimental perspectives for a better understanding of their behaviors and their potential applications in components, devices, and systems. Extensive reference lists provide opportunities to explore individual topics and classes of metamaterials in greater depth. With full-color illustrations throughout to clarify concepts and help visualize actual results, this book provides a dynamic, user-friendly resource for students, engineers, physicists, and other researchers in the areas of electromagnetic materials, microwaves, millimeter waves, and optics. It equips newcomers with a basic understanding of metamaterials and their potential applications. Advanced researchers will benefit from thought-provoking perspectives that will deepen their knowledge and lead them to new areas of investigation.

Theory, Design, and Applications Morgan & Claypool Publishers

Since the concept was first proposed at the end of the 20th Century, metamaterials have been the subject of much research and discussion throughout the wave community. More than 10 years later, the number of related published articles is increasing significantly. On the one hand, this success can be attributed to dreams of new physical objects which are the consequences of the singular properties of metamaterials. Among them, we can consider the examples of perfect lensing and invisibility cloaking. On the other hand, metamaterials also provide new tools for the design of well-known wave functions such as antennas for electromagnetic waves. The goal of this book is to propose an overview of the concept of metamaterials as a perspective on a new practical tool for wave study and engineering. This includes both the electromagnetic spectrum, from microwave to optics, and the field of acoustic waves. Contents 1. Overview of Microwave and Optical Metamaterial Technologies, Didier Lippens. 2. MetaLines: Transmission Line Approach for the Design of Metamaterial Devices, Bruno Sauviac. 3. Metamaterials for Non-Radiative Microwave Functions and Antennas, Divitha Seetharamdoo and Bruno Sauviac. 4. Toward New Prospects for Electromagnetic Compatibility, Divitha Seetharamdoo. 5. Dissipative Loss in Resonant Metamaterials, Philippe Tassin, Thomas Koschny, and Costas M. Soukoulis. 6. Transformation Optics and Antennas, André de Lustrac, Shah Nawaz Burokur and Paul-Henri Tichit. 7. Metamaterials for Control of Surface Electromagnetic and Liquid Waves, Sébastien Guenneau, Mohamed Farhat, Muamer Kadic, Stefan Enoch and Romain Quidant. 8. Classical Analog of Electromagnetically Induced Transparency, Philippe Tassin, Thomas Koschny and Costas M. Soukoulis.

Waves in Gradient Metamaterials Taylor & Francis

This fascinating book is a treatise on real space-age materials. It is a mathematical treatment of a novel concept in material science that characterizes the properties of dynamic materials—that is, material substances whose properties are variable in space and time. Unlike conventional composites that are often found in nature, dynamic materials are mostly the products of modern technology developed to maintain the most effective control over dynamic processes.

Applications of Metamaterials Springer Science & Business

Media

Metamaterials have attracted enormous interests from both physics and engineering communities in the past 20 years, owing to their powerful ability in manipulating electromagnetic waves. However, the functionalities of traditional metamaterials are fixed at the time of fabrication. To control the EM waves dynamically, active components are introduced to the meta-atoms, yielding active metamaterials. Recently, a special kind of active metamaterials, digital coding and programmable metamaterials, are proposed, which can achieve dynamically controllable functionalities using field programmable gate array (FPGA). Most importantly, the digital coding representations of metamaterials set up a bridge between the digital world and physical world, and allow metamaterials to process digital information directly, leading to information metamaterials. In this Element, we review the evolution of information metamaterials, mainly focusing on their basic concepts, design principles, fabrication techniques, experimental measurement and potential applications. Future developments of information metamaterials are also envisioned.

Acoustic Metamaterials and Phononic Crystals John Wiley & Sons

This book uses the first volume's exploration of theory, basic properties, and modeling topics to develop readers' understanding of applications and devices that are based on artificial materials. It explores a wide range of applications in fields including electronics, telecommunications, sensing, medical instrumentation, and data storage. The text also includes a practical user's guide and explores key areas in which artificial materials have developed. It includes experts' perspectives on current and future applications of metamaterials, to present a well-rounded view on state-of-the-art technologies.

Computational Photonics CRC Press

An Introduction to Metamaterials and Nanophotonics Cambridge University Press

Acoustic Metamaterials Springer Science & Business Media

The NATO Advanced Research Workshop *Bianisotropics 2002* was held in Marrakesh, Morocco, during 8-11 May 2002. This was the 9th International Conference on Electromagnetics of Complex Media, belonging to a series of meetings where the focus is on electromagnetics of chiral, bianisotropic, and other materials that may respond to electric and magnetic field excitations in special manner. The first of these meetings was held in Espoo, Finland (1993), and the following venues were Gomel, Belarus (1993), Perigueux, France (1994), State College, Pennsylvania, USA (1995), the rivers and channels between St. Petersburg and Moscow in Russia (1996), Glasgow, Scotland (1997), Brunswick, Germany (1998), and Lisbon, Portugal (2000). The present book contains full articles of several of the presentations that were given in the Marrakesh conference. In *Bianisotropics 2002*, 8 review lectures, 14 invited lectures and 68 contributed talks and posters were presented. Of these presentations, after a double review process, 28 contributions have achieved their final form on the pages to follow. From the contributions of the meeting, also another publication is being planned: a Special Issue of the journal *Electromagnetics* will be devoted to complex materials. Guest editors for this issue are Keith W. Whites and Said Zouhdi. The chairmen of *Bianisotropics 2002* conference were Said Zouhdi (Pierre et Marie Curie University - Paris) and Mohamed Arsalane (Cadi Ayyad University - Marrakesh), who were assisted by Scientists from Moroccan Universities and the International *Bianisotropics* Conference Committee.

John Wiley & Sons

Discover a comprehensive exploration of recent developments and fundamental concepts in the applications of metasurfaces. In *Electromagnetic Metasurfaces: Theory and Applications*,

distinguished researchers and authors Karim Achouri and Christophe Caloz deliver an introduction to the fundamentals and applications of metasurfaces and an insightful analysis of recent and future developments in the field. The book describes the precursors and history of metasurfaces before continuing on to an exploration of the physical insights that can be gleaned from the material parameters of the metasurface. You'll learn how to compute the fields scattered by a metasurface with known material parameters being illuminated by an arbitrary incident field, as well as how to realize a practical metasurface and relate its material parameters to its physical structures. The authors provide examples to illustrate all the concepts discussed in the book to improve and simplify reader understanding. *Electromagnetic Metasurfaces* concludes with an incisive discussion of the likely future directions and research opportunities in the field. Readers will also benefit from the inclusion of: A thorough introduction to metamaterials, the concept of metasurfaces, and metasurface precursors An exploration of electromagnetic modeling and theory, including metasurfaces as zero-thickness sheets and bianisotropic susceptibility tensors A practical discussion of susceptibility synthesis, including four-parameters synthesis, more than four-parameters synthesis, and the addition of susceptibility components A concise treatment of scattered-field analysis, including approximate analytical methods, and finite-difference frequency-domain techniques Perfect for researchers in metamaterial sciences and engineers working with microwave, THz, and optical technologies, *Electromagnetic Metasurfaces: Theory and Applications* will also earn a place in the libraries of graduate and undergraduate students in physics and electrical engineering.

Optical Metamaterials: Qualitative Models Springer Nature To meet the demands of students, scientists and engineers for a systematic reference source, this book introduces, comprehensively and in a single voice, research and development progress in emerging metamaterials and derived functional metadevices. Coverage includes electromagnetic, optical, acoustic, thermal, and mechanical metamaterials and related metadevices. Metamaterials are artificially engineered composites with designed properties beyond those attainable in nature and with applications in all aspects of materials science. From spatially tailored dielectrics to tunable, dynamic materials properties and unique nonlinear behavior, metamaterial systems have demonstrated tremendous flexibility and functionality in electromagnetic, optical, acoustic, thermal, and mechanical engineering. Furthermore, the field of metamaterials has been extended from the mere pursuit of various exotic properties towards the realization of practical devices, leading to the concepts of dynamically-reconfigurable metadevices and functional metasurfaces. The book explores the fundamental physics, design, and engineering aspects, as well as the full array of state-of-the-art applications to electronics, telecommunications, antennas, and energy harvesting. Future challenges and potential in regard to design, modeling and fabrication are also addressed.

Metamaterials John Wiley & Sons

The purpose of this book is to provide an up-to-date introduction to the time-domain finite element methods for Maxwell's equations involving metamaterials. Since the first successful construction of a metamaterial with both negative permittivity and permeability in 2000, the study of metamaterials has attracted significant attention from researchers across many disciplines. Thanks to enormous efforts on the part of engineers and physicists, metamaterials present great potential applications in antenna and radar design, sub-wavelength

imaging, and invisibility cloak design. Hence the efficient simulation of electromagnetic phenomena in metamaterials has become a very important issue and is the subject of this book, in which various metamaterial modeling equations are introduced and justified mathematically. The development and practical implementation of edge finite element methods for metamaterial Maxwell's equations are the main focus of the book. The book finishes with some interesting simulations such as backward wave propagation and time-domain cloaking with metamaterials. *Metamaterials* John Wiley & Sons

Requiring no advanced knowledge of wave propagation, *An Introduction to Metamaterials and Waves in Composites* focuses on theoretical aspects of metamaterials, periodic composites, and layered composites. The book gives novices a platform from which they can start exploring the subject in more detail. After introducing concepts related to elasticity, acoustics, and electrodynamics in media, the text presents plane wave solutions to the equations that describe elastic, acoustic, and electromagnetic waves. It examines the plane wave expansion of sources as well as scattering from curved interfaces, specifically spheres and cylinders. The author then covers electrodynamic, acoustic, and elastodynamic metamaterials. He also describes examples of transformations, aspects of acoustic cloaking, and applications of pentamode materials to acoustic cloaking. With a focus on periodic composites, the text uses the Bloch-Floquet theorem to find the effective behavior of composites in the quasistatic limit, presents the quasistatic equations of elastodynamic and electromagnetic waves, and investigates Brillouin zones and band gaps in periodic structures. The final chapter discusses wave propagation in smoothly varying layered media, anisotropic density of a periodic layered medium, and quasistatic homogenization of laminates. This book provides a launch pad for research into elastic and acoustic metamaterials. Many of the ideas presented have yet to be realized experimentally—the book encourages readers to explore these ideas and bring them to technological maturity.

An Introduction with MATLAB Springer Science & Business Media

This book provides an overview of the use of toroidal moments. This includes methods of excitation, numerical analysis, and experimental measurements of associating structures. Special emphasis is placed on understanding the fundamental physics, characteristics, and real-world applications of toroidal multipoles. This book also covers a variety of both planar and 3D meta-atom and metamolecule schemes capable to sustain toroidal moments across a wide range of spectrum. It discusses the implementation of innovative approaches, for exploring the spectral features and excitation methodologies, predicting the properties of the correlating metasystems in their excited states. An applicable text for undergraduate, graduate, and postgraduate students, this book is also of interest to researchers, theorists, and experimentalists working in optical physics, photonics, and nanotechnology.

Electromagnetic Metamaterials Springer Nature

This volume focuses on a research field that has emerged in the last decade as one of the most promising and rapidly advancing. The interest towards photonic crystals and metamaterials and their strategic importance are evident in the steadily growing rate of topical publications, the recent creation of topical journals, conferences and workshops promoted by several scientific societies, the research efforts at international level, and the number of proposed novel applications based on them. The various contributions, by renowned scientists from academia and industry, address wide-ranging topics, including aspects pertaining to modeling, phenomenologies, experiments, technologies and applications.

Metamaterials An Introduction to Metamaterials and Nanophotonics

Requiring no advanced knowledge of wave propagation, *An Introduction to Metamaterials and Waves in Composites* focuses on theoretical aspects of metamaterials, periodic composites, and layered composites. The book gives novices a platform from which they can start exploring the subject in more detail. After introducing concepts related to elasticity, acoustics, and electrodynamics in media, the text presents plane wave solutions to the equations that describe elastic, acoustic, and electromagnetic waves. It examines the plane wave expansion of sources as well as scattering from curved interfaces, specifically spheres and cylinders. The author then covers electrodynamic, acoustic, and elastodynamic metamaterials. He also describes examples of transformations, aspects of acoustic cloaking, and applications of pentamode materials to acoustic cloaking. With a focus on periodic composites, the text uses the Bloch-Floquet theorem to find the effective behavior of composites in the quasistatic limit, presents the quasistatic equations of elastodynamic and electromagnetic waves, and investigates Brillouin zones and band gaps in periodic structures. The final chapter discusses wave propagation in smoothly varying layered media, anisotropic density of a periodic layered medium, and quasistatic homogenization of laminates. This book provides a launch pad for research into elastic and acoustic metamaterials. Many of the ideas presented have yet to be realized experimentally—the book encourages readers to explore these ideas and bring them to technological maturity.

Introduction to Nano-Optics and Optical Metamaterials Springer Science & Business Media

Phenomena of Optical Metamaterials provides an overview of phenomena enabled by artificial and designed metamaterials and their application for photonic devices. The book explores the study of active metamaterials with tunable and switchable properties and novel functionalities, such as the control of spontaneous emission and enhancement. Topics addressed cover theory, modelling and design, applications in practical devices,

fabrication, characterization, and measurement, thus helping readers understand and develop new artificial, functional materials. Addresses disorder in metamaterials from the perspective of different viewpoints Introduces basic metamaterial modelling approaches and phenomena enabled by metamaterials Discusses the latest advances in metamaterials, including hyperbolic metamaterials, disorder in metamaterials, active metamaterials, quantum and atomic metamaterials
Functional Metamaterials and Metadevices SPIE Press
 Electromagnetic metamaterials are a family of shaped periodic materials which achieve extraordinary scattering properties that are difficult or impossible to achieve with naturally occurring materials. This book focuses on one such feature of electromagnetic metamaterials—the theory, properties, and applications of the absorption of electromagnetic radiation. We have written this book for undergraduate and graduate students, researchers, and practitioners, covering the background and tools necessary to engage in the research and practice of metamaterial electromagnetic wave absorbers in various fundamental and applied settings. Given the growing impact of climate change, the call for innovations that can circumvent the use of conventional energy sources will be increasingly important. As we highlight in Chapter 6, the absorption of radiation with electromagnetic metamaterials has been used for energy harvesting and energy generation, and will help to reduce reliance on fossil fuels. Other applications ranging from biochemical sensing to imaging are also covered. We hope this book equips interested readers with the tools necessary to successfully engage in applied metamaterials research for clean, sustainable energy. This book consists of six chapters. Chapter 1 provides an introduction and a brief history of electromagnetic wave absorbers; Chapter 2 focuses on several theories of perfect absorbers; Chapter 3 discusses the scattering properties achievable with metamaterial absorbers; Chapter 4 provides significant detail on the fabrication processes; Chapter 5 discusses examples of dynamical absorbers; and Chapter 6 highlights applications of metamaterial absorbers.