

Kenneth Diest *Editor*

Numerical Methods for Metamaterial Design

Numerical Methods For Metamaterial Design Topics In Applied Physics

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Genevet, Fei Ding**



Numerical Methods For Metamaterial Design Topics In Applied Physics:

Numerical Methods for Metamaterial Design Kenneth Diest, 2013-08-13 This book describes a relatively new approach for the design of electromagnetic metamaterials. Numerical optimization routines are combined with electromagnetic simulations to tailor the broadband optical properties of a metamaterial to have predetermined responses at predetermined wavelengths. After a review of both the major efforts within the field of metamaterials and the field of mathematical optimization, chapters covering both gradient based and derivative free design methods are considered. Selected topics including surrogate base optimization, adaptive mesh search, and genetic algorithms are shown to be effective gradient free optimization strategies. Additionally, new techniques for representing dielectric distributions in two dimensions, including level sets, are demonstrated as effective methods for gradient based optimization. Each chapter begins with a rigorous review of the optimization strategy used and is followed by numerous examples that combine the strategy with either electromagnetic simulations or analytical solutions of the scattering problem. Throughout the text, we address the strengths and limitations of each method as well as which numerical methods are best suited for different types of metamaterial designs. This book is intended to provide a detailed enough treatment of the mathematical methods used, along with sufficient examples and additional references, that senior level undergraduates or graduate students who are new to the fields of plasmonics, metamaterials, or optimization methods have an understanding of which approaches are best suited for their work and how to implement the methods themselves.

Time-Domain Finite Element Methods for Maxwell's Equations in Metamaterials Jichun Li, Yunqing Huang, 2012-12-15 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.

Computational Methods for Nanoscale Applications Igor Tsukerman, 2020-08-21 Positioning itself at the common boundaries of several disciplines, this work provides new perspectives on modern nanoscale problems where fundamental science meets technology and computer modeling. In addition to well known computational techniques such as finite difference schemes and Ewald summation, the book presents a new finite difference calculus of Flexible Local Approximation Methods (FLAME) that

qualitatively improves the numerical accuracy in a variety of problems **Focus on Materials** ,2006 **Science** John Michels (Journalist),2009 Since Jan 1901 the official proceedings and most of the papers of the American Association for the Advancement of Science have been included in Science *Dissertation Abstracts International* ,2008 **Metamaterials Modelling and Design** Guy Bouchitte,2017 The domain of metamaterials now covers many area of physics electromagnetics acoustics mechanics thermics or even seismology Huge literature is now available on the subject but the results are scattered Although many ideas and possible applications have been proposed which of these will emerge as a viable technology will only unfold with time This book covers the fundamental science behind metamaterials from the physical mathematical and numerical points of view focusing mainly on methods It concentrates on electromagnetic waves but would also be useful in studying other types of metamaterials It presents the structure of Maxwell equations discusses the homogenization theory in detail and includes important problems on resonance It has an entire section devoted to numerical methods finite elements Fourier modal methods scattering theory which aims to motivate a reader to implement them The book is not written as a collection of independent chapters but as a textbook with a strong pedagogical flavor Provided by publisher *Acoustic Waves in Periodic Structures, Metamaterials, and Porous Media* Noé Jiménez,Olga Umnova,Jean-Philippe Groby,2021-11-03 This book delivers a comprehensive and up to date treatment of practical applications of metamaterials structured media and conventional porous materials With increasing levels of urbanization a growing demand for motorized transport and inefficient urban planning environmental noise exposure is rapidly becoming a pressing societal and health concern Phononic and sonic crystals acoustic metamaterials and metasurfaces can revolutionize noise and vibration control and in many cases replace traditional porous materials for these applications In this collection of contributed chapters a group of international researchers reviews the essentials of acoustic wave propagation in metamaterials and porous absorbers with viscothermal losses as well as the most recent advances in the design of acoustic metamaterial absorbers The book features a detailed theoretical introduction describing commonly used modelling techniques such as plane wave expansion multiple scattering theory and the transfer matrix method The following chapters give a detailed consideration of acoustic wave propagation in viscothermal fluids and porous media and the extension of this theory to non local models for fluid saturated metamaterials along with a description of the relevant numerical methods Finally the book reviews a range of practical industrial applications making it especially attractive as a white book targeted at the building automotive and aeronautic industries **Tutorials in Metamaterials** Mikhail A. Noginov,Viktor A. Podolskiy,2011-10-25 From science fiction to science laboratories Discover the State of the Art in Photonic Metamaterials Metamaterials composite media with unusual optical properties have revolutionized the landscape of optical science and engineering over the past decades Metamaterials have transformed science fiction like concepts of superresolution imaging and optical cloaking to the realm of science laboratories and further promise to transform these into the realm of our

everyday life This new era of optical metamaterials calls for the development of experimental and theoretical methods capable of analyzing optical behavior on the multitude of scales from the nanometer scale of individual inhomogeneity to the micrometer level and the larger scale of metamaterials based devices

Tutorials in Metamaterials offers a collection of chapters that were designed as self contained tutorials describing photonic metamaterials and the state of the art in metamaterials research Chapters cover Linear and nonlinear properties of photonic metamaterials and their potential applications Fabrication techniques for optical metamaterials ranging from electron beam lithography focused ion beam milling and nanoimprint lithography to direct laser writing Recent achievements in metatamerial research at visible IR and microwave frequencies Novel applications of metamaterials for light guiding steering and refraction Efforts to compensate and eliminate optical loss by introducing optical gain into the metamaterial matrix A comprehensive overview of metamaterial photonics this reference is suitable for graduate students as well as physicists and engineers interested in entering this dynamic new field

Advances in Crystals and Elastic Metamaterials, Part 2, 2019-05-24 Multi scale Theory and Computation Volume 52 the latest release in the Advances in Applied Mechanics series draws together recent significant advances in various topics in applied mechanics Published since 1948 the book aims to provide authoritative review articles on topics in the mechanical sciences While the book is ideal for scientists and engineers working in various branches of mechanics it is also beneficial to professionals who use the results of investigations in mechanics in various applications such as aerospace chemical civil environmental mechanical and nuclear engineering Includes contributions from world leading experts that are acquired by invitation only Beneficial to scientists engineers and professionals who use the results of investigations in mechanics in various applications such as aerospace chemical civil environmental mechanical and nuclear engineering Covers not only traditional topics but also important emerging fields

Metamaterials Modelling and Design Didier Felbacq, Guy Bouchitté, 2017-07-06 The domain of metamaterials now covers many area of physics electromagnetics acoustics mechanics thermics or even seismology Huge literature is now available on the subject but the results are scattered Although many ideas and possible applications have been proposed which of these will emerge as a viable technology will only unfold with time This book covers the fundamental science behind metamaterials from the physical mathematical and numerical points of view focusing mainly on methods It concentrates on electromagnetic waves but would also be useful in studying other types of metamaterials It presents the structure of Maxwell equations discusses the homogenization theory in detail and includes important problems on resonance It has an entire section devoted to numerical methods finite elements Fourier modal methods scattering theory which aims to motivate a reader to implement them The book is not written as a collection of independent chapters but as a textbook with a strong pedagogical flavor

Metamaterials-by-Design Andrea Alù, Nader Engheta, Andrea Massa, Giacomo Oliveri, 2024-04-04 Metamaterials by Design Theory Technologies and Vision is devoted to a comprehensive review of the latest advancements and current trends in the

field of system level oriented metamaterial design methods technologies and future perspectives Starting from the theoretical and methodological motivations of this research to macro scale performance driven design of volumetric and planar metamaterials the book introduces advanced task oriented modeling approaches including specific reference to their multi scale multi physics customization in recent metamaterial science and engineering In the introduction of these concepts particular attention is paid to the illustration of the physical mechanisms and phenomena at the basis of the field manipulation capabilities enabled by metamaterials Contributions from industry and academic perspectives on active and passive metamaterial enhanced devices for communications and sensing are included The final part of the volume is aimed at providing a perspective regarding the current trends future research and application tracks in system performance driven metamaterial design methodologies and technologies included potential applications in future reconfigurable and cognitive materials Includes comprehensive review of the research developments methodologies and opportunities in the field of metamaterials by design Discusses new and emerging applications of metamaterials in microwave and terahertz spectrum photonics and optics scenarios Reviews performance driven metamaterial design methodologies and technologies in communications and sensing

Metamaterials Tie Jun Cui, David Smith, Ruopeng Liu, 2009-10-30 Metamaterials Theory Design and Applications goes beyond left handed materials LHM or negative index materials NIM and focuses on recent research activity Included here is an introduction to optical transformation theory revealing invisible cloaks EM concentrators beam splitters and new type antennas a presentation of general theory on artificial metamaterials composed of periodic structures coverage of a new rapid design method for inhomogeneous metamaterials which makes it easier to design a cloak and new developments including but not limited to experimental verification of invisible cloaks FDTD simulations of invisible cloaks the microwave and RF applications of metamaterials sub wavelength imaging using anisotropic metamaterials dynamical metamaterial systems photonic metamaterials and magnetic plasmon effects of metamaterials

Frequency Domain Hybrid Finite Element Methods for Electromagnetics John Leonidas Volakis, Kubilay Sertel, Brian C. Usner, 2006 This book provides a brief overview of the popular Finite Element Method FEM and its hybrid versions for electromagnetics with applications to radar scattering antennas and arrays guided structures microwave components frequency selective surfaces periodic media and RF materials characterizations and related topics It starts by presenting concepts based on Hilbert and Sobolev spaces as well as Curl and Divergence spaces for generating matrices useful in all engineering simulation methods It then proceeds to present applications of the finite element and finite element boundary integral methods for scattering and radiation Applications to periodic media metamaterials and bandgap structures are also included The hybrid volume integral equation method for high contrast dielectrics and is presented for the first time Another unique feature of the book is the inclusion of design optimization techniques and their integration within commercial numerical analysis packages for shape and material design To aid the reader with the method s utility an entire chapter is

devoted to two dimensional problems The book can be considered as an update on the latest developments since the publication of our earlier book *Finite Element Method for Electromagnetics* IEEE Press 1998 The latter is certainly complementary companion to this one *Architected Metamaterials: Design Principles and Properties* Nikhil Gupta,Caleb Beckwith,2025-09-21 This book demonstrates the variety of metamaterials in presented in the scholarly research literature their compositions manufacturing methods and applications It reviews critical work appearing in over 400 papers published within the last five years discussing these materials This volume summarizes the main findings of this topic for a graduate level beginners in the field of mechanical engineering materials science manufacturing engineering and electrical engineering *Structural Modeling of Metamaterials* Vladimir I. Erofeev,Igor S. Pavlov,2020-11-13 This book discusses the theoretical foundations of the structural modeling method applied to metamaterials This method takes into account the parameters of the crystal lattice the size of the medium particles as well as their shape and constants of force interactions between them It provides mathematical models of metamaterials that offer insights into the qualitative influence of the local structure on the effective elastic moduli of the considered medium and into performing theoretical estimations of these quantities This book is useful for researchers working in the fields of solid mechanics physical acoustics and condensed matter physics as well as for graduate and postgraduate students studying mathematical modeling methods

Metamaterial Analysis and Design Habib Ammari,Bryn Davies,2023-11-06 Metamaterials are advanced composite materials which have exotic and powerful properties Their complicated microstructures make metamaterials challenging to model requiring the use of sophisticated mathematical techniques This book uses a from first principles approach based on boundary integral methods and asymptotic analysis to study a class of high contrast metamaterials These mathematical techniques are applied to the problem of designing graded metamaterials that replicate the function of the cochlea

Innovative Numerical Approaches for Multi-Field and Multi-Scale Problems Kerstin Weinberg,Anna Pandolfi,2016-06-24 This book provides readers with a detailed insight into diverse and exciting recent developments in computational solid mechanics documenting new perspectives and horizons The topics addressed cover a wide range of current research from computational materials modeling including crystal plasticity micro structured materials and biomaterials to multi scale simulations of multi physics phenomena Particular emphasis is placed on pioneering discretization methods for the solution of coupled non linear problems at different length scales The book written by leading experts reflects the remarkable advances that have been made in the field over the past decade and more largely due to the development of a sound mathematical background and efficient computational strategies The contents build upon the 2014 IUTAM symposium celebrating the 60th birthday of Professor Michael Ortiz to whom this book is dedicated His work has long been recognized as pioneering and is a continuing source of inspiration for many researchers It is hoped that by providing a taste of the field of computational mechanics the book will promote its popularity among the mechanics and physics communities

Numerical Modeling in Materials Science and Engineering Michel Rappaz, Michel Bellet, Michel Deville, 2010-03-11

This book introduces the concepts and methodologies related to the modelling of the complex phenomena occurring in materials processing After a short reminder of conservation laws and constitutive relationships the authors introduce the main numerical methods finite differences finite volumes and finite elements These techniques are developed in three main chapters of the book that tackle more specific problems phase transformation solid mechanics and fluid flow The two last chapters treat inverse methods to obtain the boundary conditions or the material properties and stochastic methods for microstructural simulation This book is intended for undergraduate and graduate students in materials science and engineering mechanical engineering and physics and for engineering professionals or researchers who want to get acquainted with numerical simulation to model and compute materials processing

Wave Dynamics, Mechanics and Physics of Microstructured Metamaterials Mezhlum A. Sumbatyan, 2019-05-17 This book addresses theoretical and experimental methods for exploring microstructured metamaterials with a special focus on wave dynamics mechanics and related physical properties The authors use various mathematical and physical approaches to examine the mechanical properties inherent to particular types of metamaterials These include Boundary value problems in reduced strain gradient elasticity for composite fiber reinforced metamaterials Self organization of molecules in ferroelectric thin films Combined models for surface layers of nanostructures Computer simulation at the micro and nanoscale Surface effects with anisotropic properties and imperfect temperature contacts Inhomogeneous anisotropic metamaterials with uncoupled and coupled surfaces or interfaces Special interface finite elements and other numerical and analytical methods for composite structures

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