

Kenneth Diest *Editor*

Numerical Methods for Metamaterial Design

Numerical Methods For Metamaterial Design Topics In Applied Physics

Ricardo Marqués, Ferran Martín, Mario Sorolla



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

Emerging Technologies in Computational Sciences for Industry, Sustainability and Innovation Matteo Giacomini, Simona Perotto, Gianluigi Rozza, 2025-12-24 This book presents up to date state of the art for industrial mathematics and covers emerging topics in computational sciences Mathematical models and computational methods have gained an increasing importance in the simulation of real world and industrial problems The employment of such methodologies deeply changed the standard ways of conceiving daily industrial production and strategies for sustainable exploitation of modern cities The goal pursued by this book is twofold On the one hand cases of successful interaction between mathematics and industry are presented Special emphasis is devoted to the benefits provided by the transfer of knowledge in different fields of applications including the social challenges of sustainable development On the other hand groundbreaking ideas and emerging technologies in computational science are discussed to foster cross fertilization of academic solutions and real world problems Math to Product M2P is meant to establish a platform for proposal discussion and promotion of current and new trends in industry sustainability and innovation with the goal of supporting creative and interdisciplinary thoughts Scientific technical areas covered include transfer of knowledge innovation in design computational science and engineering industrial optimization processes sustainable mobility aerospace automotive nautical and naval engineering Target audience is made up by grad students and researchers in the field

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.

Metamaterials Modelling and Design Guy Bouchitte, 2017 The domain of metamaterials now covers many areas 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.

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

Frequency Domain Hybrid Finite Element Methods in Electromagnetics John. L Volakis, Kubilay Sertel, Brian C Usner, 2022-06-01 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

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 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

An Invitation to Metamaterials Didier Felbacq, 2025-04-03 This book provides a thorough introduction to the fundamental principles and cutting edge applications of metamaterials It offers a balanced perspective combining theoretical experimental and computational approaches Topics covered include rapidly evolving areas such as metasurfaces quantum metamaterials and nonlinear metamaterials The book also extends its scope beyond optics to explore applications in acoustics thermal science mechanics and even seismology A dedicated chapter discusses topological insulators providing detailed insights into this advanced topic The text is designed for advanced graduate students and early career researchers in the field of metamaterials Specialists in the field will also benefit from the book s presentation of new developments and innovative approaches Two chapters focus on advanced mathematical methods including fiber bundles Chern numbers pseudodifferential operators and scattering theory These sections are crafted to be reasonably self contained with references provided for readers who wish to explore these topics further **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

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

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 **Architected Metamaterials: Design Principles and Properties** Nikhil Gupta, Caleb Beckwith, 2025-09-21 This book demonstrates the variety of metamaterials 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 **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 **Metamaterials with Negative Parameters** Ricardo Marqués, Ferran Martín, Mario Sorolla, 2011-09-20 The first general textbook to offer a complete overview of metamaterial theory and its microwave applications Metamaterials with Negative Parameters represents the only unified treatment of metamaterials available in one convenient book Devoted mainly to metamaterials that can be characterized by a negative effective permittivity and or permeability the book includes a wide overview of the most important topics scientific fundamentals and technical applications of metamaterials Chapter coverage includes the electrodynamics of left handed media synthesis of bulk metamaterials synthesis of metamaterials in planar technology microwave applications of metamaterial concepts and advanced and related topics including SRR and CSRR based admittance surfaces magneto and electro inductive waves and sub diffraction imaging devices A list of problems and references is included at the end of each chapter and a bibliography offers a complete up to date representation of the current state of the art in metamaterials Geared toward students and professionals alike Metamaterials with Negative Parameters is an ideal textbook for postgraduate courses and also serves as a valuable introductory reference for scientists and RF microwave engineers **Numerical Modeling in Materials Science and Engineering** Michel Rappaz, Michel Bellet, Michel O. Deville, 2002-11-05 Computing application to materials science is one of the fastest growing research areas This book introduces the concepts and methodologies related to the modeling of the complex phenomena occurring in materials processing It is intended for undergraduate and graduate students in materials science and engineering mechanical engineering and physics and for engineering professionals or researchers **Metamaterial Inspired Electromagnetic Applications** Balamati Choudhury, 2017-05-04 This book focuses on the role of soft computing based electromagnetic computational engines in design and optimization of a wide range of electromagnetic applications In addition to the theoretical background of metamaterials and soft computing techniques the book discusses novel electromagnetic applications such as tensor analysis for invisibility cloaking metamaterial structures for cloaking

applications broadband radar absorbers and antennas The book will prove to be a valuable resource for academics and professionals as well as military researchers working in the area of metamaterials Numerical Methods in Mechanics of Materials Ken P. Chong, 2017 In the dynamic digital age the widespread use of computers has transformed engineering and science A realistic and successful solution of an engineering problem usually begins with an accurate physical model of the problem and a proper understanding of the assumptions employed With computers and appropriate software we can model and analyze complex physical systems and problems However efficient and accurate use of numerical results obtained from computer programs requires considerable background and advanced working knowledge to avoid blunders and the blind acceptance of computer results This book provides the background and knowledge necessary to avoid these pitfalls especially the most commonly used numerical methods employed in the solution of physical problems It offers an in depth presentation of the numerical methods for scales from nano to macro in nine self contained chapters with extensive problems and up to date references covering Trends and new developments in simulation and computation Weighted residuals methods Finite difference methods Finite element methods Finite strip layer prism methods Boundary element methods Meshless methods Molecular dynamics Multiphysics problems Multiscale methods

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web keep your upper arms at your side bend from your elbows to pull your lower arms up toward your head 3 repeat times
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