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Manipulation of Surface Waves through Metasurfaces John Wiley & Sons

The book presents an engineering approach for the development of metamaterials and metasurfaces with emphasis on application in antennas. It offers an in-depth study, performance analysis and extensive characterization on different types of metamaterials and metasurfaces. Practical examples included in the book will help readers to enhance performance of antennas and also develop metamaterial-based absorbers for a variety of applications. Key Features Provides background for design and development of metamaterial structures using novel unit cells Gives in-depth performance study of miniaturization of microstrip antennas Discusses design and development of both transmission and reflection types, metasurfaces and their practical applications. Verifies a variety of Metamaterial structures and Metasurfaces experimentally The target audience of this book is postgraduate students and researchers involved in antenna designs. Researchers and engineers interested in enhancing the performance of the antennas using metamaterials will find this book extremely useful. The book will also serve as a good reference for developing artificial materials using metamaterials and their practical applications. Amit K. Singh is Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Technology Jammu, India. He is a Member of the IEEE, USA. Mahesh P. Abegaonkar is

Associate Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Senior Member of the IEEE, USA. Shiban Kishen Koul is Emeritus Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Life Fellow of the Institution of Electrical and Electronics Engineering (IEEE), USA, a Fellow of the Indian National Academy of Engineering (INAE), and a Fellow of the Institution of Electronics and Telecommunication Engineers (IETE). *Handbook of Metamaterial-Derived Frequency Selective Surfaces* CRC Press

The dielectric metasurfaces have been widely recognized as a low-loss platform allowing for manipulation of the near- and far-fields. However, the field of light-emitting dielectric metasurfaces is less developed. The main objective of this thesis is to demonstrate how dielectric metasurfaces can improve and control the emission of nanoscale light sources coupled to them. This includes the experimental realization of coupled photonic systems consisting of emitters and dielectric metasurfaces, development of optical setups for characterization of the emission properties, and numerical simulations to support the experimental data and to analyze the underlying physical mechanisms.

Design and Characterization of

Optical Metasurface Systems Cambridge University Press
The five-volume set may serve as a comprehensive reference on electromagnetic analysis and its applications at all frequencies, from static fields to optics and photonics. The material includes micro- and nanomagnetics, the new generation of electric machines, renewable energy, hybrid vehicles, low-noise motors; antennas and microwave devices, plasmonics, metamaterials, lasers, and more.Written at a level accessible to both graduate students and engineers, Electromagnetic Analysis is a comprehensive reference, covering methods and applications at all frequencies (from statics to optical). Each volume contains pedagogical/tutorial material of high archival value as well as chapters on state-of-the-art developments.
Encyclopedia of Interfacial Chemistry Frontiers Media SA
A metafilm (also referred to as a metasurface) is the surface equivalent of a metamaterial. More precisely, a metafilm is a surface distribution of suitable chosen electrically small scatterers. Metafilms are becoming popular as an alternative to full three-dimensional metamaterials. Unfortunately, many papers in the literature present incorrect interpretations and mischaracterizations of these metafilms. In fact, some of the characterizations

presented in the literature result in non-unique parameters for a uniquely defined metafilm. In this paper we discuss an appropriate interpretation and characterization of metafilms and present a correct manner to characterize a metafilm. Additionally, we illustrate the error that results from an incorrect characterization of metafilms. We present various examples to emphasize these points. Finally we present a retrieval approach for determining the uniquely defined quantities (the electric and magnetic susceptibilities of its constituent scatterers) that characterize a metafilm.

Multifunctional Antennas and Arrays for Wireless Communication Systems

Frontiers Media SA

The importance of optics is increasing in our daily lives, from medical devices to the cameras that facilitate global communications. Because of their universal use, the size, scale and quality of optical elements grow in importance for technological innovations. Over the last few decades, the downscaling of complementary metal–oxide–semiconductor (CMOS) sensors thanks to Moore's law have resulted in a dramatic reduction in the size of optical systems, including imaging and non-imaging systems. However, most optical systems are now limited in size by the optical element itself, not the sensor. One promising candidate for enabling further miniaturization is metasurfaces, which are ultrathin elements comprising arrays of subwavelength-spaced scattering elements. These metasurface elements can achieve a broad class of functionalities in a flat form factor, transforming the phase, amplitude, and polarization of incident electromagnetic radiation. While metasurfaces provide a large number of degrees of freedom to design complex optical functions, their full potential and applicability have yet to be discovered. This dissertation will investigate a variety of different metasurface designs and expand on the functionality of these optical elements as solutions for imaging and non-imaging systems.In the body of this dissertation, we investigated how to design dielectric metasurface subwavelength scattering elements to optimize them for a variety of functions. The designs discussed represent the research progress made towards developing optical sensors for imaging and non-imaging systems that are more compact. In particular, this Thesis highlights designs for silicon nitride based scattering elements for 1D and 2D EDOF metasurfaces in the visible regime for full color imaging. This is followed by a more general methodology that uses EDOF lenses in conjunction with computational imaging to eliminate broadband chromatic aberrations. Lastly, there are proposed designs for composite metasurface visors that can overcome several challenges of near eye augmented reality visors, including reducing bulkiness, addressing FOV limitations, minimizing chromatic aberrations and improving the see-through quality. The demonstrated approach may find applications in microscopy, planar cameras, medical imaging, and augmented reality.

Advanced Photonics Metasurfaces: Design, Fabrication, and Applications CRC Press MULTIFUNCTIONAL ANTENNAS AND ARRAYS FOR WIRELESS COMMUNICATION SYSTEMS Offers an up-to-date discussion of multifunctional antennas and arrays for wireless communication systems Multifunctional Antennas and Arrays for Wireless Communication Systems is a comprehensive reference on state-of-the-art reconfigurable antennas and 4G/5G communication antennas. The book gives a unique perspective while giving a comprehensive overview of the following topics: Frequency reconfigurable antennas Pattern reconfigurable antennas Polarization reconfigurable antennas Reconfigurable antennas using Liquid Metal, Piezoelectric, and RF MEMS MIMO and 4G/5G wireless communication antennas Metamaterials and metasurfaces in reconfigurable antennas Multifunctional antennas for user equipments (UEs) Defense related antennas and applications Flat panel phased array antennas The book is a valuable resource for the practicing engineer as

well as for those within the research field. As wireless communications continuously evolves, more and more functionally will be required, and thus multifunctional antennas and RF systems will be necessary. These multifunctional antennas will require a degree of reconfigurability, and this book discusses various methods which enable this. The main topics of frequency, pattern, and polarization reconfigurability is first discussed. Methods utilizing unique materials and devices, both real and artificial are discussed. The book also delves into 4G/5G antennas as it relates to MIMO, and millimeter-wave phased arrays. Finally, there is a section on defense related multifunctional RF antenna systems.
Engineering of Highly Efficient Metasurfaces for Flat Optics Springer
This book presents the technology of millimetre waves and Terahertz (THz) antennas. It highlights the importance of moderate and high-gain aperture antennas as key devices for establishing point-to-point and point-to-multipoint radio links for far-field and near-field applications, such as high data-rate communications, intelligent transport, security imaging, exploration and surveillance systems. The book provides a comprehensive overview of the key antenna technologies developed for the mm wave and THz domains, including established ones – such as integrated lens antennas,

advanced 2D and 3D horn antennas, transmit and reflect arrays, and Fabry-Perot antennas – as well as emerging metasurface antennas for near-field and far-field applications. It describes the pros and cons of each antenna technology in comparison with other available solutions, a discussion supplemented by practical examples illustrating the step-by-step implementation procedures for each antenna type. The measurement techniques available at these frequency ranges are also presented to close the loop of the antenna development cycle. In closing, the book outlines future trends in various antenna technologies, paving the way for further developments. Presenting content originating from the five-year ESF research networking program 'Newfocus' and co-authored by the most active and highly cited research groups in the domain of mm- and sub-mm-wave antenna technologies, the book offers a valuable guide for researchers and engineers in both industry and academia.

Aperture Antennas for Millimeter and Sub-Millimeter Wave Applications Frontiers Media SA

The THz quantum-cascade vertical-external-cavity surface-emitting-laser (QC-VECSEL) is a recently developed approach for designing high-power, electrically pumped THz lasers with excellent beam quality and broadband tunability. The key component of the QC-VECSEL is an amplifying reflectarray metasurface, based on a subwavelength array of surface radiating metal-metal waveguide antenna elements loaded with QC-laser gain material. Despite its importance, the gain properties of the QC-metasurface are designed by simulation and have only been verified indirectly through observation of the QC-VECSEL lasing characteristics, or by passive FTIR reflectance measurements at room-temperature. THz time-domain spectroscopy (TDS) has been widely used to investigate gain spectra and laser dynamics of THz QC-lasers based on various ridge waveguide geometries. In this thesis, I describe my construction of a THz TDS system and present the first direct spectral measurement using reflection-mode THz TDS of an amplifying QC-metasurface resonant at 2.6 THz under different conditions. The large surface-radiating aperture of the metasurface (1.5 1.5 mm2 in this case) eases free-space TDS measurements compared to ridge waveguide QC-devices with sub-wavelength sized facets.

Optical Vortices: Generation and Detection
CRC Press
This volume provides a consolidated reference for the applications of frequency selective surfaces (FSS) technology in different sectors such as wireless communications, smart buildings, microwave and medical industries. It covers all aspects of metamaterial FSS technology starting from

theoretical simulation, fabrication and measurement all the way to actual hardware implementation. Also included are in-depth discussions on the design methodologies of metamaterial FSS structures and their practical implementation in devices and components. It will be of interest to researchers and engineers working on developing metamaterial-FSS technology.

Nonlinear Meta-Optics

Springer

Since the emergence of diffraction gratings containing periodic unit cells, innumerable advances in theoretical studies and practical applications have emerged. Recently, these classic structures have been categorized as subsets of "meta-surfaces" or "meta-materials" in which periodically aligned wavelength-scale features manipulate all key properties of the electromagnetic waves in a desired manner for a wide variety of applications. This includes manipulating of amplitude, phase, spectral distribution, polarization state, and local mode structure of light in the various available spectral expressions. Among the significant characteristic properties of metasurfaces is the coupling of incident light to laterally propagating leaky Bloch modes in the subwavelength regime when the periodicity of the unit cell is moderately smaller than the free-space wavelength. This property, which manifests itself as a resonance at certain wavelengths, is called "guided mode resonance (GMR)" or "leaky mode resonance (LMR)". These structures offer novel properties and functionalities in ultra-thin device dimensions which make them potential replacements for conventional and bulky optical devices. Extensive studies have been conducted to realize the periodic structures in different materials (metals, dielectric, and semiconductors or their hybrid compositions) employing various fabrication methods for different wavelength ranges in 1D or 2D configuration. Thus, on account of the wide variety of material compositions and lattice architectures, the design space is vast. Various numerical techniques such as rigorous coupled-wave analysis (RCWA), finite element method (FEM), and finite-difference time-domain (FDTD) can be used to implement simulations and obtain the precise optical responses of the metasurfaces. In addition, inverse optimization methods, efficiently provide optimized physical parameters in order to obtain a particular desired spectral response. However, these computational methods which are based on solving heavy and complicated equations and do not always provide comprehensive insight into underlying physics of the numerically obtained optical spectra.In this dissertation, we present a comprehensive physical description of resonant metasurfaces based on exact solutions of the Rytov formulation. We define a clear transition wavelength between the resonance subwavelength region and the deep-subwavelength region. This transition point, analytical in a special case, is not available presently in the literature. In addition, we design, fabricate, and characterize various novel GMR-based optical devices such as metamaterial polarizers, nanoimprinted nanocomposite filters, multipart unit-cell metasurfaces, ultrahigh-Q resonant dual-grating metamembranes, and fiber-facet integrated optical filters and sensors.

A Discussion on the Interpretation and Characterization of Metafilms BoD – Books on Demand

Dielectric Metamaterials: Fundamentals, Designs and Applications links fundamental Mie scattering theory with the latest dielectric metamaterial research, providing a valuable reference for new and experienced researchers in the field. The book begins with a historical, evolving overview of Mie scattering theory. Next, the authors describe how to apply Mie theory to analytically solve the scattering of electromagnetic waves by subwavelength particles. Later chapters focus on Mie resonator-based metamaterials, starting with microwaves where particles are much smaller than the free space wavelengths. In addition, several chapters focus on wave-front engineering using dielectric metasurfaces and the nonlinear optical effects, spontaneous emission manipulation, active devices, and 3D effective media using dielectric metamaterials. Highlights a crucial link in fundamental Mie scattering theory with the latest dielectric metamaterial research spanning materials, design and applications Includes coverage of wave-front engineering and 3D metamaterials Provides computational codes for calculating and simulating Mie resonances *Electromagnetic Metasurfaces* Woodhead Publishing Metamaterials and metasurfaces are developing exciting new frontier researches on reconfigurable materials with promising applications on tunable and active devices. The combination of metamaterials and microsystems not only uncap the controllability limits of optical metamaterials, but also pave the way for vast applications. This book focuses on structural reconfiguration of metasurfaces and metamaterials using microsystems, which have previously been developed for tiny machines and droplets formations. It covers multi-disciplinary researches on reconfigurable metamaterials and metasurfaces revealing their potential applications on densely integrated devices with working frequencies ranging from GHz to infrared region. Topics like MEMS metamaterials, frequency selective surface, photonic reconfigurable metasurfaces, and microfluidic metamaterials are just a few examples, which present lively research communities within the scope of this book. This book is intended for undergraduate and graduate students who are interested in fundamental science and technology of micro-optics and artificial materials, researchers in the field of reconfigurable and tunable metamaterials, and engineers working on tunable lens, Lidar, beam steering devices, or other applications.

Metasurfaces: Physics and Applications World Scientific

Metamaterials, including their two-dimensional counterparts, are composed of subwavelength-scale artificial particles. These materials have novel electromagnetic properties, and can be artificially tailored for various applications. Based on metamaterials and metasurfaces, many abnormal physical phenomena have been realized, such as negative refraction, invisible cloaking, abnormal reflection and focusing, and many new functions and devices have been developed. The effective medium theory lays the foundation for design and application of metamaterials and metasurfaces, connecting metamaterials with real world applications. In this Element, the authors combine these essential ingredients, and aim to make this Element an access point to this field. To this end, they review classical theories for dielectric functions, effective medium theory, and effective parameter extraction of metamaterials, also introducing front edge technologies like metasurfaces with theories, methods, and potential applications. Energy densities are also included.

Theory and Applications of Electromagnetic Metamaterials Springer Nature

Space–time transformations as a design tool for a new class of composite materials (metamaterials) have proved successful recently. The concept is based on the fact that metamaterials can mimic a transformed but empty space. Light rays follow trajectories according to Fermat's principle in this transformed electromagnetic, acoustic, or elastic space instead of laboratory space. This allows one to manipulate wave behaviors with various exotic characteristics such as (but not limited to) invisibility cloaks. This book is a collection of works by leading international experts in the fields of electromagnetics, plasmonics, elastodynamics, and diffusion waves. The experimental and theoretical contributions will revolutionize ways to control the propagation of sound, light, and other waves in macroscopic and microscopic scales. The potential applications range from underwater camouflaging and electromagnetic invisibility to enhanced biosensors and protection from harmful physical waves (e.g., tsunamis and earthquakes). This is the first book that deals with transformation physics for all kinds of waves in one volume, covering the newest results from emerging topical subjects such as transformational plasmonics and thermodynamics.

Frontiers in Physics - Rising Stars Springer Nature

Frequency mixing is an essential nonlinear process with extensive applications in photonics, chemistry, biology, and energy sciences. Traditional nonlinear crystals have weak nonlinear responses and light beams need long propagation distances in the crystals to accumulate a significant wave mixing in practice. However, wave mixing in such bulky crystals results in stringent phase-matching requirements and bulk nonlinear crystals are not compatible with modern “flat” optics concept that enables complete control of the phase-front of the output beam but requires optical medium with subwavelength thickness. Fortunately, the emerging of metasurfaces has provided an efficient method to generate the large nonlinear response on nanoscale. The metasurfaces have enabled the development of “flat” optical elements with the intrinsic benefit of small thickness, intricate control of the optical wavefront, and, in case of nonlinear optical elements, relaxed phase-matching constraints. In my Ph.D. dissertation, I focus on the second-order intersubband polaritonic nonlinear metasurfaces. These structures combine enormous intersubband nonlinear response in III-V semiconductor heterostructures and field enhancement of plasmonic nano-resonators. Our earlier research has demonstrated giant nonlinear responses for the second harmonic generation in metasurfaces. In this dissertation, I propose several approaches to improve the performance of second harmonic generation metasurfaces and extend their functionality to difference-frequency and sum-frequency generation in the mid-infrared range. For the first part of this study, I have demonstrated new multiquantum-well designs for second harmonic generation with materials have much narrower linewidth compared with previous materials. This leads to a conversion efficiency of 1.2%. Second, I have demonstrated the mid-infrared difference-frequency generation in polaritonic nonlinear metasurface for the first time. The optimization of the metasurface, the theoretical investigation of the saturation effect, the fabrication of the metasurface, and the experimental characterization of the metasurface have been discussed. The effective nonlinear susceptibility is 340 nm/V and the differencefrequency generation conversion efficiency of this metasurface is 0.13%. I have also demonstrated the mid-infrared sum-frequency generation in a polaritonic nonlinear metasurface. Both the theoretical analysis of the saturation effect and the experimental characterization of the metasurface have been illustrated. The upconversion efficiency of this metasurface is 0.03% and the nonlinear susceptibility is 158 nm/V. In addition, as the prospect of the SFG metasurfaces, the performance of metasurfaces under extremely high pump intensity has been discussed and the metasurface designs for high conversion efficiency have been proposed. For the last part of this study, metasurfaces in the THz range have been explored. These metasurfaces are designed to generate 4~6 THz with a difference-frequency generation process from polaritonic metasurfaces at room temperature. The theoretical analysis, sample design, and preliminary experimental results have been discussed

Dielectric Metamaterials and Metasurfaces in Transformation Optics and Photonics Woodhead Publishing

This book is a printed edition of the Special Issue "Metasurfaces: Physics and Applications" that was published in Applied Sciences

Compendium On Electromagnetic Analysis - From Electrostatics To Photonics: Fundamentals And

Applications For Physicists And Engineers (In 5 Volumes) John Wiley & Sons
Provides systematic coverage of the theory, physics, functional designs, and engineering applications of advanced electromagnetic surfaces.
Effective Medium Theory of Metamaterials and Metasurfaces MDPI
The book presents an engineering approach for the development of metamaterials and metasurfaces with emphasis on application in antennas. It offers an in-depth study, performance analysis and extensive characterization on different types of metamaterials and metasurfaces. Practical examples included in the book will help readers to enhance performance of antennas and also develop metamaterial-based absorbers for a variety of applications. Key Features Provides background for design and development of metamaterial structures using novel unit cells Gives in-depth performance study of miniaturization of microstrip antennas Discusses design and development of both transmission and reflection types, metasurfaces and their practical applications. Verifies a variety of Metamaterial structures and Metasurfaces experimentally The target audience of this book is postgraduate students and researchers involved in antenna designs. Researchers and engineers interested in enhancing the

performance of the antennas using metamaterials will find this book extremely useful. The book will also serve as a good reference for developing artificial materials using metamaterials and their practical applications. Amit K. Singh is Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Technology Jammu, India. He is a Member of the IEEE, USA. Mahesh P. Abegaonkar is Associate Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Senior Member of the IEEE, USA. Shiban Kishen Koul is Emeritus Professor at the Centre for Applied Research in Electronics at the Indian Institute of Technology Delhi. He is a Life Fellow of the Institution of Electrical and Electronics Engineering (IEEE), USA, a Fellow of the Indian National Academy of Engineering (INAE), and a Fellow of the Institution of Electronics and Telecommunication Engineers (IETE).

Dielectric Metamaterials
John Wiley & Sons
In recent years, we have witnessed a rapid expansion of using super-thin metasurfaces to manipulate light or electromagnetic wave in a subwavelength scale. However, most designs are confined to a passive scheme and monofunctional operation, which hinders considerably the promising applications of the metasurfaces. Specifically, the tunable and multifunctional

metasurfaces enable to facilitate switchable functionalities and multiple functionalities which are extremely essential and useful for integrated optics and microwaves, well alleviating aforementioned issues. In this book, we introduce our efforts in exploring the physics principles, design approaches, and numerical and experimental demonstrations on the fascinating functionalities realized. We start by introducing in Chapter 2 the "merging" scheme in constructing multi-functional metadevices, paying particular attention to its shortcomings issues. Having understood the merits and disadvantages of the "merging" scheme, we then introduce in Chapter 3 another approach to realize bifunctional metadevices under linearly polarized excitations, working in both reflection and transmission geometries or even in the full space. As a step further, we summarizes our efforts in Chapter 4 on making multifunctional devices under circularly polarized excitations, again including designing principles and devices fabrications/characterizati ons. Starting from Chapter 5, we turn to introduce our efforts on using the "active" scheme to construct multifunctional metadevices under linearly polarized wave operation. Chapter 6 further concentrates on how to employ the tunable strategy to achieve helicity/frequency controls of the circularly polarized waves in reflection geometry. We finally conclude this book in Chapter 7 by presenting our perspectives on future directions of metasurfaces and metadevices.

Surface Electromagnetics

Elsevier

Provides a comprehensive discussion of planar transmission lines and their applications, focusing on physical understanding, analytical approach, and circuit models Planar transmission lines form the core of the modern high-frequency communication, computer, and other related technology. This advanced text gives a complete overview of the technology and acts as a comprehensive tool for radio frequency (RF) engineers that reflects a linear discussion of the subject from fundamentals to more complex arguments. Introduction to Modern Planar Transmission Lines: Physical, Analytical, and Circuit Models Approach begins with a discussion of waves on transmission lines and waves in material medium, including a large number of illustrative examples from published results. After explaining the electrical properties of dielectric media, the book moves on to the details of various transmission lines including waveguide, microstrip line, co-planar waveguide, strip line, slot line, and coupled transmission lines. A number of special and advanced topics are discussed in later chapters, such as fabrication of planar transmission lines, static variational methods for planar transmission lines, multilayer planar transmission lines, spectral domain analysis, resonators, periodic lines and surfaces, and metamaterial realization and circuit models. Emphasizes modeling using physical concepts, circuit-models, closed-form expressions, and full derivation of a large number of expressions Explains advanced mathematical treatment, such as the variation method, conformal mapping method, and SDA Connects each section of the text with forward and backward cross-referencing to aid in personalized self-study Introduction to Modern Planar Transmission Lines is an ideal book for senior undergraduate and graduate students of the subject. It will also appeal to new researchers with the inter-disciplinary background, as well as to engineers and professionals in industries utilizing RF/microwave technologies.