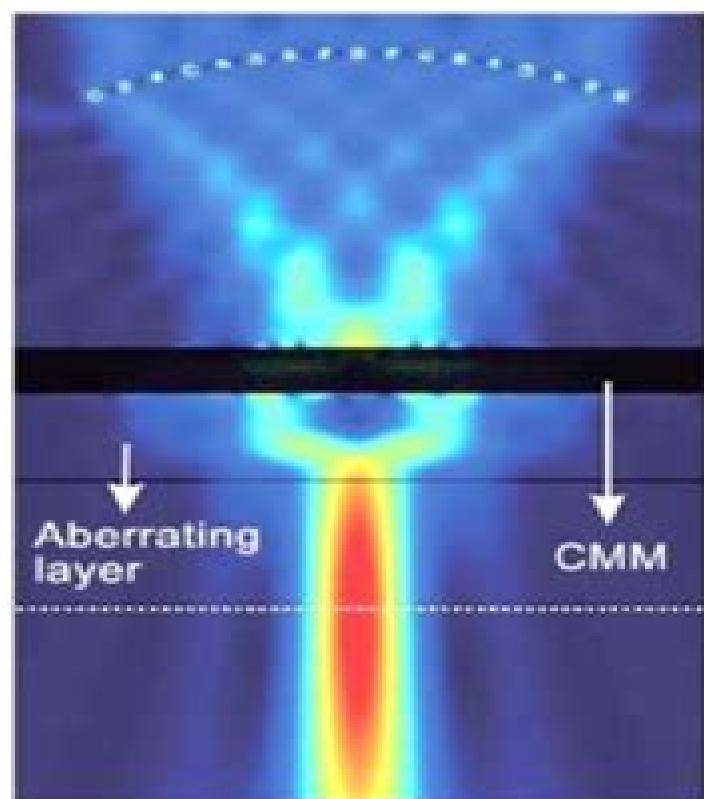


**(a)**



**(b)**

# Acoustic Metamaterials

**Gengkai Hu,Xiaoming Zhou**

## **Acoustic Metamaterials**

**Acoustic Metamaterials** Richard V. Craster, Sébastien Guenneau, 2012-12-06 About the book This book is the first comprehensive review on acoustic metamaterials novel materials which can manipulate sound waves in surprising ways which include collimation focusing cloaking sonic screening and extraordinary transmission It covers both experimental and theoretical aspects of acoustic and elastic waves propagating in structured composites with a focus on effective properties associated with negative refraction lensing and cloaking Most related books in the field address electromagnetic metamaterials and focus on numerical methods and little or no experimental section Each chapter will be authored by an acknowledged expert amongst the topics covered will be experimental results on non destructive imaging cloaking by surface water waves flexural waves in thin plates Applications in medical ultrasound imaging and modeling of metamaterials will be emphasized too The book can serve as a reference for researchers who wish to build a solid foundation of wave propagation in this class of novel materials

**Dynamic Equivalent Modeling of Acoustic Metamaterials** Nansha Gao, Jie Deng, 2022-10-17 This book derives physical models from basic principles studies the effect of equivalent models on the dynamic characteristics of phononic crystals and acoustic metamaterials and analyzes the physical mechanisms behind vibration and noise reduction It first summarizes the research status of vibration and noise reduction and research progress in phononic crystals and acoustic metamaterials Based on this one dimensional periodic beam two dimensional thin plate with circular hole and corresponding gradient structures are introduced and their dynamic characteristics are discussed in detail Therefore different equivalent methods for different models are proposed through theoretical analysis modal analysis and transmission rate analysis Finally a Helmholtz type acoustic metamaterial i e a multi layer slotted tube acoustic metamaterial is studied Aiming at the low frequency band gap of this model a theoretical model for solving the inverse problem of acousto electric analogue equivalent is proposed and the effect of structural parameters on the low frequency band gap is studied using this equivalent model This book closely revolves around how to conduct equivalent research on artificially fabricated periodic structures The methods and conclusions presented in this book provide a new theoretical basis for the application of artificial woven periodic structures in the field of low frequency vibration reduction and noise reduction and are also an innovation in the discipline of vibration and noise control This book is suitable for undergraduate students graduate students and teachers in vibration and noise majors in universities and can also provide references for engineering and technical personnel in related fields

**Fundamentals and Applications of Acoustic Metamaterials** Vicente Romero-Garcia, Anne-Christine Hladky-Hennion, 2019-09-11 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

**Acoustic Metamaterials** Richard Craster, Sébastien Guenneau, 2024-11-16 The revised edition of this book offers an expanded review of acoustic metamaterials novel materials which can manipulate sound waves surface Rayleigh waves and water waves in surprising ways which include collimation focusing negative refraction passive and active cloaking sonic screening and extraordinary transmission It covers both experimental and theoretical aspects of acoustic and elastic waves propagating in structured composites with a focus on effective properties associated with negative refraction lensing and cloaking Updated chapters cover filtering effects extraordinary transmission sub wavelength imaging via tomography or time reversal techniques cloaking via transformation acoustics elastodynamics and acoustic scattering cancellation For this revised edition six new chapters have been introduced to reflect recent developments in experimental acoustics and metasurfaces including acoustic impedance gratings and mirror symmetric metamaterials phononic subsurfaces time modulated and topological crystals The latter two are illustrated by simple Python program examples The broad scope gives the reader an overview of the state of the art in acoustic metamaterials research and an indication of future directions and applications It will serve as a solid introduction to the field for advanced students and researchers in physics applied mathematics and mechanical engineering and a valuable reference for those working in metamaterials and related areas

**Acoustic Metamaterials** Hong-Xiang Sun, Yong Ge, Shou-Qi Yuan, 2025-07-23 This book explores the rapidly evolving field of acoustic metamaterials focusing on their ability to manipulate sound waves through asymmetric transmission acoustic focusing and acoustic asymmetric focusing It introduces innovative research methods and achievements such as the use of underwater plate like metamaterials airborne metamaterials and phase controlled metamaterials to achieve precise control over sound propagation in 2D and 3D spaces Readers will be particularly interested in the novel applications of these materials in medical ultrasound underwater detection acoustic communication and noise reduction as well as the development of advanced devices like broadband AF lenses and thermoacoustic phase controlled metamaterials The book is enriched with detailed illustrations tables and clear theoretical explanations making complex concepts accessible It provides valuable insights into the design and modulation of high performance acoustic devices offering both foundational knowledge and advanced techniques for practical applications This work is particularly beneficial for researchers engineers and graduate students in acoustics materials science and related fields as it bridges the gap between theoretical research and real world applications

**Theory and Design of Acoustic Metamaterials** Perngjin Frank Pai, Guoliang Huang, 2015 This book presents the most recent theoretical developments and numerical experimental validations of new metamaterials and phononic crystals for the

broadband absorption of elastic waves and vibrations in structures These nine chapters explore many aspects of phononic crystals and acoustic elastic metamaterials including sound attenuation absorption extraordinary transmission wave broadband mitigation wave steering cloaking via the transformation method optimization of phononic crystals and active acoustic metamaterials    Acoustic Metamaterials and Phononic Crystals Pierre A. Deymier,2013-01-13 This comprehensive book presents all aspects of acoustic metamaterials and phononic crystals The emphasis is on acoustic wave propagation phenomena at interfaces such as refraction especially unusual refractive properties and negative refraction A thorough discussion of the mechanisms leading to such refractive phenomena includes local resonances in metamaterials and scattering in phononic crystals    Acoustic Metamaterials and Phononic Crystals Pierre A. Deymier,2013-01-13 This comprehensive book presents all aspects of acoustic metamaterials and phononic crystals The emphasis is on acoustic wave propagation phenomena at interfaces such as refraction especially unusual refractive properties and negative refraction A thorough discussion of the mechanisms leading to such refractive phenomena includes local resonances in metamaterials and scattering in phononic crystals    **Acoustic Waves in Periodic Structures, Metamaterials, and Porous Media** Noé Jiménez,Olga Umnova,Jean-Philippe Groby,2021 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    **New Acoustics Based on Metamaterials** Woon Siong Gan,2017-12-10 This book highlights the acoustical metamaterials capability to manipulate the direction of sound propagation in solids which in turn control the scattering diffraction and refraction the three basic mechanisms of sound propagation in solids This gives rise to several novel theories and applications and hence the name new acoustics As an introduction the book mentions that symmetry of acoustic fields is the theoretical framework of acoustical metamaterials This is then followed by describing that acoustical metamaterials began with locally resonant sonic materials which ushered in the

concept of negative acoustic parameters such as mass density and bulk modulus This complies with form invariance of the acoustic equation of motion which again exemplifies the symmetry property of acoustic fields **Bianisotropy in Passive Acoustic Metamaterials** Caleb Frederick Sieck,2017 Metamaterials are composite materials whose dynamic microstructure results in macroscopically observable properties beyond those available in nature The emergence of metamaterials has enabled unprecedented control of electromagnetic elastodynamic and acoustic wave propagation and has led to technologies including invisibility cloaks super and hyper lenses and subwavelength bandgaps These effects are made possible through the hidden degrees of freedom afforded by the dynamic microstructure Analytically the macroscopically observed parameters are the result of a dynamic homogenization procedure using weighted field averages over a representative volume element of the composite After performing the homogenization procedure constitutive relations reveal the dependencies between macroscopic fields and metamaterial properties Recent research has demonstrated that dynamic homogenization results in constitutive relations that are coupled which is not the case for most traditional materials This general effect is well known in electromagnetism and is known as bianisotropy but the analogous effect in elastodynamics and acoustics was discovered more recently and is also often referred to as Willis coupling However most current homogenization schemes are modeled to determine macroscopic properties in the same form as traditional materials and therefore do not account for coupled constitutive relations Additionally in the absence of embedded sources metamaterial parameters are non unique which allows for macroscopic descriptions that only include traditional parameters or traditional parameters and coupling parameters For acoustic metamaterials the traditional properties are density and compressibility The additional coupling parameters result in macroscopic momentum density and volume strain fields that are coupled due to both being dependent on macroscopic acoustic particle velocity and pressure fields This dissertation explores the analogs between bianisotropy in electromagnetism elastodynamics and acoustics and the consequences of neglecting these effects on the physical interpretation of acoustic metamaterial parameters The analogs are used to provide a qualitative understanding of the origin of coupling parameters and a multiple scattering homogenization procedure is derived to demonstrate coupling due to asymmetry and nonlocal effects Additionally the restrictions of causality passivity and reciprocity on acoustic metamaterial parameters are derived and it is demonstrated that macroscopic descriptions that neglect bianisotropy in one dimensional acoustic metamaterials do not in general satisfy these restrictions

**Acoustic Metamaterials with Controllable Transmission** Laura Enrique Feliu,2020 This project deals with the design and analysis of sound scattering in acoustic metamaterials with the aim to realize a controllable transmission response First a so called stealth acoustic metamaterial is studied This is a metamaterial with non periodic rigid scatterers that suppress acoustic scattering at predefined frequencies Although the literature reports a single stealth one dimensional configuration here we show that this configuration is not unique for the specified geometric parameters and that the sound transparent behaviour can be achieved by simply

relocating the scatterers To optimize their positions we have developed four algorithms generating feasible configurations which are based on a random choice and three optimization procedures The algorithms are not restricted to the stealth behaviour but are shown to perform well to achieve any desired transmission value This opens bright perspectives to the development of non periodic acoustic metamaterials with controllable transmission In particular we show how a plane wave front can be changed to a half sin function form The acoustic characteristics of the proposed metamaterials have been studied analytically and the obtained results are verified by finite element simulations **Acoustic Metamaterials** Sz-Chin Steven Lin,2012-08 Acoustic metamaterials are of growing interest due to their ability to manipulate the propagation of acoustic waves in an extraordinary manner to benefit various applications such as communications biosensing and medical diagnosis and therapy Among various construction methods of acoustic metamaterials artificially engineered elastic periodic structures known as phononic crystals PCs are the strongest candidates since they exhibit complete phononic band gaps and negative refractions due to the periodicity of the structure In this book a new class of acoustic metamaterials gradient index phononic crystal GRIN PC is introduced to overcome the limitations of regular PCs and further enrich the control over acoustic waves GRIN PCs with different gradient profiles are designed to guide acoustic waves in extraordinary manners that are not shown in nature or regular PCs A practical method for tuning the phononic band gaps of a PC is investigated The concepts presented in this book serve as important foundations for the future development of acoustic devices

**Anisotropic and Negative Acoustic Index Metamaterials** Lee Ren Fok,2010 Microstructured materials are used in material science and engineering to attain desired material properties Acoustic metamaterials are a rapidly growing area in this field of engineered materials that use deep subwavelength microstructures to attain exotic acoustic properties unavailable in nature These properties such as negative acoustic index allow unprecedented capabilities such as sub diffraction limit resolution which have the potential to greatly improve existing technologies like high intensity focused ultrasound sound shielding and ultrasonic imaging as well as create the entirely new ones like acoustic cloaking and energy trapping Two acoustic material properties were pursued in this dissertation anisotropic density and negative acoustic index Anisotropic density in a fluid acoustic metamaterial was pursued for use in a 2D acoustic hyperlens Originally developed to image sub diffraction limit electromagnetic information in the far field the theory behind the hyperlens imaging method in acoustics is presented and the performance is shown to be directly related to the density anisotropy magnitude An acoustic metamaterial composed of alternating deep subwavelength layers of air and brass is then shown theoretically and numerically to attain the necessary density anisotropy with a three order of magnitude difference in component amplitudes Experiments using a 2D cylindrical acoustic hyperlens constructed from this metamaterial confirm a significant portion of the evanescent components are converted into propagating components at the lens exit resulting in far field acoustic imaging of information far below the diffraction limit Development of a negative acoustic index fluid metamaterial was motivated by the

reversed wave phenomena leading to a perfect lens Negative bulk modulus and density are shown in simulations to result from the combination of Helmholtz and rod spring resonators which creates a band in the power ultrasound frequency range with negative real acoustic index components Following a several design changes to accommodate the available experimental facilities samples of this metamaterial were tested and indeed found to attain a negative real component of acoustic index However intrinsic loss and design restrictions led to a small real to imaginary index component ratio severely limiting the application prospects of this metamaterial Work on active acoustic metamaterials to overcome these and other problems follows with simulations indicating piezoelectric elements in water may be used as gain elements to amplify damped waves or as direct replacements for passive resonators that both combat loss and broaden the bandwidth of anomalous properties

Metamaterial-based Acoustic Devices for Audio and Ultrasound Applications Jun Ji, 2024 Acoustic metamaterials are artificially engineered materials or structures that exhibit exotic acoustic properties that are not found in nature They have been a highly active research area to control the behavior of acoustic waves in recent years Acoustic metasurfaces as the 2D version of acoustic metamaterials have opened up unprecedented possibilities for controlling acoustic waves at will offering a solution of molding wave propagation within a thin sheet of structures While the majority of the research in acoustic metamaterials and metasurfaces are curiosity driven and have shown promising progress in overcoming the fundamental physical limitations of acoustics there has been a scarcity of acoustic metamaterials research that can have a direct and immediate impact on real world applications This thesis makes contributions to the fields of acoustic metamaterials by examining the challenges of some real world applications at audio and ultrasound frequencies and putting forward novel metamaterial based acoustic devices that overcome these limitations In this thesis we start to tackle the ultra low frequency below 100 Hz sound absorption problem which is a long standing issue in room acoustics by designing a low frequency broadband high absorption near omnidirectional acoustic metasurface absorber at a deep subwavelength thickness guided by the causality limit Then we extend the sound absorption in room acoustics to HVAC system fundamentally from a one port system without acoustic transmission to a two ports system with acoustic transmission A near perfect absorption 99% absorption is demonstrated when the spatial period of monopole dipole resonators is close to one working wavelength 95% of the wavelength The condition for perfect absorption is to render degenerate monopole dipole resonators critically coupled Besides absorption loudness enhancement of acoustic transducers is another challenging issue at low audio frequency band By leveraging the resonant coupling effect between the transducer and metamaterial resonances a 3 7 dB broadband sound pressure level SPL improvement of acoustic radiation in the bass range 50 700 Hz can be achieved In addition to airborne acoustics at low audio frequency enormous underwater applications at ultrasound frequency exist One of the application challenges along this direction is the weak ultrasound transmission through a metallic wall due to the significant impedance mismatch between water and the wall which impedes wireless ultrasonic power transfer and data transmission in aeronautic

and aerospace engineering and nuclear engineering We design a pillar based acoustic metamaterial for wireless and contactless ultrasonic power transfer and data transmission through a metallic wall by leveraging the pillar's vertical elongation mode Acoustic Metamaterials and Wave Control Gengkai Hu,Xiaoming Zhou,2020-11-30 As an emerging interdisciplinary field acoustic metamaterials have generated increasing interests for diverse engineering applications from noise and vibration alleviation to super resolution imaging The book starts with a simple mass in mass chain model to illustrate the concept of negative mass due to internal resonance and its impact on wave transmission The practical transformation theory for controlling acoustic waves is explained Pentamode acoustic metamaterials and related cloaking design are also included Finally the book ends up with the sub diffraction limited acoustic imaging based on metamaterials This comprehensive title gives a broad overview on different aspects of acoustic metamaterials with a balance of theory and experiment It is not only a collection of the authors original works to these interesting topics but also the main achievements in this field Researchers academics professionals and graduate students in the fields of mechanical engineering condensed matter physics new materials applied physics and general readers of noise and vibration controls will find this exciting book to be an indispensable reference material A New Design of Acoustic Metamaterials 2017

### **Functional**

**Metamaterials and Metadevices** Xingcun Colin Tong,2017-09-14 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 Acoustic and Mechanical Metamaterials for Various Applications Fuyin Ma,Siyuan Dai,Han Jia,Yan-Feng Wang,Yong Xiao,2022-09-23 The Manipulation of Sound with Acoustic Metamaterials Gareth Paul Ward,2017

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## **Table of Contents Acoustic Metamaterials Acoustic Metamaterials**

1. Understanding the eBook Acoustic Metamaterials Acoustic Metamaterials
  - The Rise of Digital Reading Acoustic Metamaterials Acoustic Metamaterials
  - Advantages of eBooks Over Traditional Books
2. Identifying Acoustic Metamaterials Acoustic Metamaterials
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Acoustic Metamaterials Acoustic Metamaterials
  - User-Friendly Interface
4. Exploring eBook Recommendations from Acoustic Metamaterials Acoustic Metamaterials
  - Personalized Recommendations
  - Acoustic Metamaterials Acoustic Metamaterials User Reviews and Ratings
  - Acoustic Metamaterials Acoustic Metamaterials and Bestseller Lists
5. Accessing Acoustic Metamaterials Acoustic Metamaterials Free and Paid eBooks

- Acoustic Metamaterials Acoustic Metamaterials Public Domain eBooks
- Acoustic Metamaterials Acoustic Metamaterials eBook Subscription Services
- Acoustic Metamaterials Acoustic Metamaterials Budget-Friendly Options

6. Navigating Acoustic Metamaterials Acoustic Metamaterials eBook Formats

- ePUB, PDF, MOBI, and More
- Acoustic Metamaterials Acoustic Metamaterials Compatibility with Devices
- Acoustic Metamaterials Acoustic Metamaterials Enhanced eBook Features

7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Acoustic Metamaterials Acoustic Metamaterials
- Highlighting and Note-Taking Acoustic Metamaterials Acoustic Metamaterials
- Interactive Elements Acoustic Metamaterials Acoustic Metamaterials

8. Staying Engaged with Acoustic Metamaterials Acoustic Metamaterials

- Joining Online Reading Communities
- Participating in Virtual Book Clubs
- Following Authors and Publishers Acoustic Metamaterials Acoustic Metamaterials

9. Balancing eBooks and Physical Books Acoustic Metamaterials Acoustic Metamaterials

- Benefits of a Digital Library
- Creating a Diverse Reading Collection Acoustic Metamaterials Acoustic Metamaterials

10. Overcoming Reading Challenges

- Dealing with Digital Eye Strain
- Minimizing Distractions
- Managing Screen Time

11. Cultivating a Reading Routine Acoustic Metamaterials Acoustic Metamaterials

- Setting Reading Goals Acoustic Metamaterials Acoustic Metamaterials
- Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Acoustic Metamaterials Acoustic Metamaterials

- Fact-Checking eBook Content of Acoustic Metamaterials Acoustic Metamaterials
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development

- Exploring Educational eBooks
- 14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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