



Editorial

Introduction to the special issue on cloaking of wave motion

The explosion of interest in cloaking of wave motion over the last half decade has been motivated, arguably, by two themes: first, the fact that demonstrable cloaking is actually achievable [1], and secondly, by the realization that the wave equation, transformation of coordinates, and material properties, are intertwined with one another. While the experimental stimulus [1] defines the starting point for wide interest in cloaking, the broader realization of the general applicability of transformation optics lies behind the spread of cloaking from electromagnetics to other wave types. Transformation optics, or its version in acoustics, elasticity, etc., explains the fact that nearly every type of wave motion has its own potential cloaking mechanism.

The Special Issue provides in one place theory, simulation, and applications of transformation optics, cloaking, and related approximations, to wave motion of different types. The papers in this issue treat cloaking of electromagnetic, acoustic and elastic wave motion. Mechanisms for passive cloaking, active cloaking, anti-cloaking, and wave cancelation, are described. In the course of the eight papers, the reader will encounter exotic materials with anisotropic density, plasmonic properties, pentamode behavior, inextensibility, and non-symmetric stress. The following is a synopsis of these contributions.

Castaldi et al. [2] examine the interaction of cloaking and anti-cloaking devices. Anti-cloaking provides a method to restore the scattering response of a cloaked target. It has application to sensors by reducing the scattering response while maintaining field-sensing capabilities. The paper develops a three-dimensional full-wave solution for a combination of spherical cloak and anti-cloak under plane-wave incidence. Interactions between the cloak and anti-cloak are illustrated for various configurations, with implications for approximate implementations that require the use of double-positive media only.

Guild et al. [3] describe a passive method for reducing scattering strength that employs intelligent use of cancelation layers. This approach provides an alternative to transformation based cloaking of electromagnetic waves at moderately long wavelengths. The cancelation mechanism is based on the use of a single homogeneous thin layer covering the object of interest leading to scattering suppression in a particular range of frequencies. The paper examines the physical basis of scattering cancelation by a uniform thin layer for both electromagnetic and acoustic waves. Two distinct scattering cancelation regions are obtained within the available parameter space: a non-resonant plasmonic cloaking region and an anti-resonant cloaking region, which are identified and compared in both the electromagnetic and acoustic domains. The paper discusses analogies and differences between both mechanisms and describes implications for practical implementation in electromagnetic and acoustic cloaking.

Dupont et al. [4] consider layered spherical acoustic cloaks. Alternating homogeneous isotropic concentric layers yield, via homogenization using effective medium theory, a suitable approximation to a spherical cloaking device. Numerical examples examine near and far-fields and illustrate the broadband nature of the cloaking approximation. Issues related to the singularity of the point-to-volume singular transformation required for perfect cloaking are discussed, and practical workarounds are described. The paper includes discussion and examples of invisibility carpets which mimic reflection by a flat ground.

Torrent and Sánchez-Dehesa [5] study homogenized periodically layered cylindrical structures as approximations to acoustic cloaking devices. The multilayer approach allows one to obtain a cloaking effect by combining homogeneous and isotropic fluid-like materials to give effectively anisotropic mass density in the dynamic regime. The paper focuses on examining the range of possibilities based on the homogenization of only two alternating fluid-like materials. Particular emphasis is given to the study of imperfect cloaks, for which the singular nature of the acoustic parameters required for ideal cloaking is not necessary.

Scandrett et al. [6] consider layered structures in the context of acoustic cloaking based on pentamode materials with isotropic densities. The use of pentamode materials leads to a different type of cloaking mechanism than that obtained through effective anisotropic density. A straightforward but novel optimization technique is presented for finding optimal material parameters of layered broadband acoustic cloaks. The method is illustrated by application to the spherical cloak. The paper examines and discusses the feasibility of constructing effective broadband acoustic cloaks with a small number of pentamode layers having isotropic densities.

Vasquez et al. [7] consider active cloaking devices. Unlike passive cloaking, the active cloak requires knowledge of the incident wave, but the active cloak does not require the use of exotic metamaterials. The problem in constructing an active cloak is to determine the simplest configuration of sources that cancels out the field in the cloaked region without significantly radiating

waves. The paper shows that this can be achieved using as few as three multipolar point sources, although more can be used. The method is illustrated through numerical examples of a two-dimensional cloak made with three active sources.

Norris and Shuvalov [8] extend the concept of transformation optics to linear elasticity. They answer the question of what is the most general type of metamaterial that can mimic the effects of an elastic region and thereby form a passive elastic wave cloaking device. The paper shows that the transformed material properties are non-unique, and form a spectrum of materials ranging from non-local constitutive behavior exemplified by the Willis model, to purely local elastic response with non-symmetric stress.

Olsson [9] also considers the application of transformation optics to elastic wave motion, but with particular attention given to elastic materials with inextensibility conditions. The paper explores an extension of earlier results on internally kinematically constrained elastic materials to the case of time domain reflection from a composite planar layer of rather general anisotropy. The results, analytical and numerical, convincingly demonstrate that different fiber-reinforced anisotropic slabs may have identical reflection properties. Also, under some circumstances, the reflection of energy from incident time domain shear waves can be substantially diminished.

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