Transformation Acoustics, Phononic Stuctures and Applications

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Transformation acoustics (TA) offers the acoustical designer the potential to alter sound propagation in an exact manner that satisfies the wave equation regardless of frequency, high or low. This is the reason why TA is the foundation for exotic effects such as acoustic cloaking. Cloaking however requires acoustic properties that are anisotropic and difficult to realize in practice. After a review of the physical foundations of TA and its extension to elastic waves, the talk will concentrate on the special case of isotropic TA and its applications. The motivation for focusing on isotropic TA is that materials with the required properties can be readily realized by a wide variety of homogenized structures. We concentrate on underwater acoustic devices and show that quasi-phononic structures with unit cells comprising circular, square and other shaped cylinders in water provide the range of required properties. We will show that isotropic TA devices require only a change in effective bulk modulus, but not density. Several implications are explored: first, the ability of conformal mappings to yield highly accurate focusing lenses is described. These devices can act, by reciprocity, as monopole to highly one-way-wave radiators. The boundary of the TA region places constraints on the ability to properly match the impedance to the exterior acoustic medium. A class of focusing devices is described that are optimally matched in both impedance and focusing. Numerical examples and data from experimental measurements will demonstrate these ideas.