Active Control of Light Scattering in Disordered Photonic Media by Gain and Loss

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Abstract

Wave scattering through disordered media has intrigued scientific community for centuries. Multiple scattering of light in opaque systems results in a non-uniform distribution of the intensity at various position within the disordered medium. For sufficiently strong scattering, in the limit of the regime of Anderson localization, light wave hardly penetrates the medium and is essentially backscattered as a result of strong destructive interferences in the forward direction.

One of the modern challenges in the last decade has been the control of multiple scattering, to extract useful information from the light wave. Due to the availability of high-resolution spatial light modulator, remarkable progress has been made in the field of photonics, in the study of controlling light transmission through disorder media [1,2] for applications such as biomedical imaging, focusing [3], and efficient transmission [4]. Recent theoretical and experimental studies show that non-Hermitian photonic structures which obey PT-symmetries in the presence of balanced gain and loss can give rise to unique functionalities such as unidirectional invisibility [5], loss induced lasing [6], non-reciprocal light transmission [7], laser with absorber [8], that are not possible to realize with Hermitian potentials.

PT-symmetry is broken in disordered systems. Yet, recent theoretical investigations [9] predict that in disordered systems described by a given distribution of the refractive index, it is possible to find a corresponding distribution of the imaginary part of the refractive index, such that a wave will traverse freely the scattering medium without any backscattering or intensity variation along the sample. This concept of perfect transmission through disordered system has been recently verified for acoustic waves in a one dimensional (1D) strongly scattering system limited to 8 scatterers [10]. This has not yet been observed in optical systems. In this work, we consider a 1D scattering photonic structure, in which gain and loss can be controlled and distributed along the sample. We show how an opaque medium in the deep regime of Anderson localization can be turned into a transparent medium. We demonstrate how multiple light scattering can be controlled by intelligent shaping of the gain and loss profile along the sample: for any scattering arrangement and any wavelength, we can find a particular distribution for which, backscattering is completely canceled and transmission is almost unity at any position along the sample.

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