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Probing the nature of wave propagation with transmission times

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We explore in microwave measurements and numerical simulations in random single and multichannel media with and without dissipation or gain the relationships between the transmission time, t, which equals the spectral derivative of the phase of the transmitted field, the density of states, ρ, and the net energy in the interior of the sample for unit flux incident in all channels, $\bar{u}$. We find that each of these may be expressed in terms of a sum over quasi-normal modes, with each term in the sum involving only the central frequency, and the leakage and dissipation rates of a single mode. In absorbing media and below a threshold in gain in amplifying media, the average transmission time is independent of absorption, gain or scattering strength. Above this threshold, the transmission time decreases with gain and finally becomes negative. The negative transmission time is associated with a reshaping of a wide incident pulse. In quasi-1D, the average transmission time of specific transmission eigenchannels varies with loss, but the average of their sum is conserved. These results demonstrate the robustness of the modal description of wave propagation in random media. The application of these results to Fano resonances between the continuum edge state and modes in the bandgap of disordered topological insulators will be discussed.

Work done with Mathieu Davy, Zhou Shi, and Yuhao Kang