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New perspectives on waves in random media: Speckle, modes, transmission eigenchannels, and focusing[1]

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The understanding of electron localization and conductance fluctuations has been advanced by utilizing notions of speckle, modes, and transmission eigenchannels. These concepts cannot be probed directly for electronic systems but can be explored for classical waves utilizing spectra of field transmission coefficients between arrays of points on the incident and output surfaces of ensembles of random samples. This is illustrated in microwave measurements of transmission through random waveguides in the Anderson localization transition. These experiments supply the link between the statistics of intensity and conductance and show that transmitted wave can be decomposed simultaneously into the underlying quasi-normal modes and transmission eigenchannels of the sample. The power of each of these approaches and the richness of the links between them will be illustrated by examples that reveal new aspects of wave propagation. The delayed onset of transmission following pulse excitation is shown to be the result of destructive interference between highly correlated speckle patterns of neighboring modes, while the falling decay rate at later times reflects the incoherent decay of increasingly prominent long-lived modes. We determine the individual eigenvalues τ_n of the transmission matrix and achieve nearly complete transmission in opaque diffusive samples. We demonstrate that when reflection at the sample interface is taken into account, the spacing between average values of $\ln\tau_n$ is equal to the inverse of the bare conductance, in accord with predictions by Dorokhov [1]. We find that the distribution of total transmission relative to the conductance is determined by the effective number of transmission eigenvalues, $N_{eff} = \left(\sum_{n=1}^{N} \tau_n\right)^2 / \sum_{n=1}^{N} \tau_n^2$, which provides the link between the statistics of intensity and conductance. For diffusive waves, N_{eff} is the inverse of the degree of intensity correlation. The contrast between the peak and background of maximally focused radiation in the transmitted wave, achieved when the incident is phase conjugated relative to the selected focal point, is equal to $(1 + N_{eff})$.

[1] O. N. Dorokhov, Solid State Commun. **51**, 381 (1984).

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