Nonergodic extended phases in wave transport: from disordered to quasiperiodic systems coupled to electromagnetic cavities

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Abstract

Wave transport in complex media is fundamentally governed by the nature of quasimodes at the microscopic scale. In three-dimensional disordered systems, waves may undergo a phase transition from diffusion to Anderson localization, characterized by exponentially localized modes. A notable exception is found in electromagnetic waves, where their vector nature inhibits the onset of Anderson localization.
Using the point-dipole model in three-dimensions, we show that both scalar and vector (electromagnetic) waves exhibit a non-ergodic extended phase characterized by fractal quasimodes across a wide range of disorder strengths. While scalar waves eventually transition into a localized regime at high disorder, electromagnetic waves persist in the non-ergodic extended phase, never becoming localized.
Furthermore, we identify two additional physical systems that support non-ergodic extended phases: the two-dimensional quantum percolation model and the one-dimensional Aubry-André model coupled to electromagnetic cavities. These findings collectively demonstrate the robustness of non-ergodic extended phases and open new avenues for engineering anomalous wave transport in disordered media.

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