Lattice Boundaries and Dimensionality Crossover on Anderson Localization of Light

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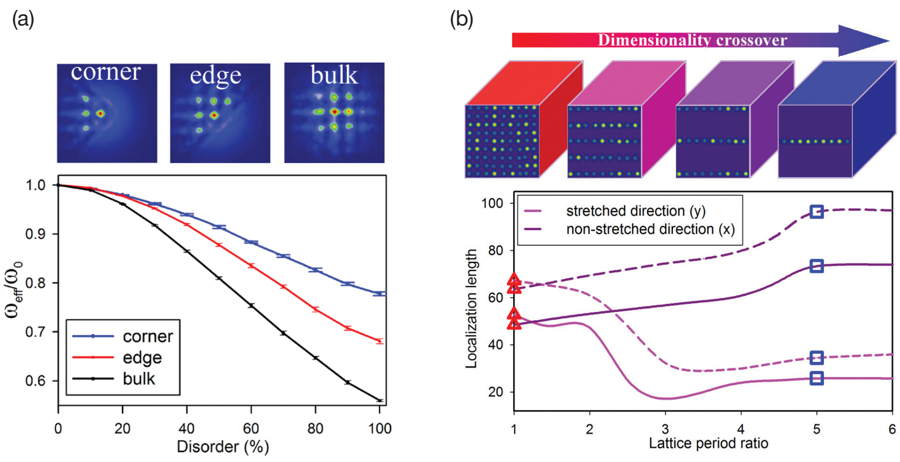
Anderson localization (AL) is one of the most fascinating universal phenomena in disordered systems physics.[1] It still excites interest in a variety of systems, including light waves, despite its 50-year history. Anderson's original work in 1958 demonstrated that AL strongly depends on the dimension of the medium. With respect to the localization of light, many facets of the phenomenon still remain in the dark.

Transverse optical AL in two-dimensional (2-D) photonic lattices, nonlinear (NL) effects and quasilattices were considered experimental in 2007. The intricacies of the dimensional influence on localization are still unexplored. The question of how AL changes at the boundaries of discrete photonic media is also not yet understood. Another unexplored region in this field is the localization of counterpropagating (CP) beams, which requires media of finite longitudinal extension. Since CP beams are inherently unstable in NL media, this brings dynamical effects in AL to the forefront of disordered systems research.

We have recently achieved progress in each of the above-mentioned topics.[3-6] We extended the concept of transverse AL to mutually incoherent CP beams, where we observed the dynamical localization of time-changing beams.[4] We elucidated the effect of boundaries on AL of light in truncated 2-D photonic lattices in a NL medium.[5] Suppression of AL at the edges and corners is demonstrated, so that—quite counterintuitively—stronger disorder is needed near the boundaries to obtain the same localization as in the bulk material. We found that the level of suppression depends on the location in the lattice (edge vs. corner), as well as on disorder strength.

Most recently, we analyzed how system dimensionality affects light localization.[6] A systematic study of the dependence on both the disorder strength and the nonlinearity on AL strength of such a system was carried out. Strong NL regimes exist in which 1-D localization is more pronounced than the 2-D counterpart, opposite to the linear regime case.



(a) Anderson localization of light near boundaries of disordered photonic lattices. The graph shows the effective beam width at the lattice output vs. the disorder level for corner, edge and bulk modes. The corresponding localized modes are shown on the left. (b) Localization of light in the dimensionality crossover system. Lattice stretching is displayed with two intermediate cases (top row). Localization length in the transition regime is shown vs. the lattice period ratio in the linear (solid lines) and the nonlinear regime (dashed lines) along stretched and non-stretched transverse directions. Red triangles represent 2-D lattice localization lengths. Blue squares represent the corresponding 1-D lattice localization lengths.

To investigate transition from 2-D to 1-D in a disordered photonic lattice, we devised a system with dimensionality crossover. An array of widely separated 1-D lattices is reached by starting with a 2-D square photonic lattice, and increasing the lattice period along one transverse direction and keeping the period along the other direction fixed. We are able to gradually switch from the 2-D to the 1-D case with this lattice stretching. By investigating intermediate cases, we can determine the transition of quantities of interest describing localization, e.g., the effective beam width and the localization length from 2-D to 1-D values. For example, such a dimensionality crossover is characterized by two different localization lengths along different transverse directions. We are convinced that our lines of inquiry in the AL of light open new research avenues into this fascinating field. ◭

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