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Aperiodic space-inhomogeneous quantum walks: Localization properties, energy spectra, and enhancement of entanglement

We study the localization properties, energy spectra, and coin-position entanglement of the aperiodic discrete-time quantum walks. The aperiodicity is described by spatially dependent quantum coins distributed on the lattice, whose distribution is neither periodic (Bloch-like) nor random (Anderson-like). Within transport properties we identified delocalized and localized quantum walks mediated by a proper adjusting of aperiodic parameter. Both scenarios are studied by exploring typical quantities (inverse participation ratio, survival probability, and wave packet width), as well as the energy spectra of an associated effective Hamiltonian. By using the energy spectra analysis, we show that the early stage the inhomogeneity leads to a vanishing gap between two main bands, which justifies the predominantly delocalized character observed for $\nu < 0.5$. With increase of ν arise gaps and flat bands on the energy spectra, which corroborates the suppression of transport detected for $\nu > 0.5$. For ν high enough, we observe an energy spectra, which resembles that described by the one-dimensional Anderson model. Within coin-position entanglement, we show many settings in which an enhancement in the ability to entangle is observed. This behavior brings new information about the role played by aperiodicity on the coin-position entanglement for static inhomogeneous systems, reported before as almost always reducing the entanglement when comparing with the homogeneous case. We extend the analysis in order to show that systems with static inhomogeneity are able to exhibit asymptotic limit of entanglement.

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