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Disorder-free localization in quantum walks

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The localization phenomenon usually happens due to the existence of disorder in a medium. Nevertheless, specific quantum systems allow dynamical localization solely due to internal interactions. We study a discrete-time quantum walker which exhibits disorder-free localization. The quantum walker moves on a one-dimensional lattice and interacts with on-site spins by coherently rotating them around a given axis at each step. Since the spins do not have their dynamics, the system poses the local spin components along the rotation axis as many conserved moments. When the interaction is weak, the spread of the walker shows sub-diffusive behavior, having downscaled ballistic tails in the evolving probability distribution at intermediate time scales. However, as the interaction gets stronger, the walker gets exponentially localized in the complete absence of disorder in both lattice and initial state. Using a matrix-product-state ansatz, we investigate the relaxation and entanglement dynamics of the on-site spins due to their coupling with the quantum walker. Surprisingly, even in the delocalized regime, entanglement growth and relaxation occur slowly, unlike the majority of the other models displaying a localization transition.

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