Floquet topological phases of non-unitary quantum walks with $\mathcal{PT}$ symmetry

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A quantum walk, that is, a synthetic quantum system whose dynamics is described by a time-evolution operator, provides potential applications for quantum computing and information as well as quantum simulators. It is further interesting that the quantum walk possesses novel topological phases[1,2,3] akin to those of Floquet topological insulators, which are topological insulators driven by a time-periodic field. Recently, a non-unitary one-dimensional quantum walk dynamics associated with gain and loss is implemented in the fiber loops experiment [4]. The experiment shows that the quasienergy of the non-unitary time-evolution operator in the homogeneous system is kept to be real. This provides convincing evidence that the non-unitary time-evolution operator of this system possesses $\mathcal{PT}$ symmetry (combined parity and time-reversal symmetry). However, the definition of $\mathcal{PT}$ symmetry for the time-evolution operator has not yet been fully understood.

In this work, at first, we directly identify the $\mathcal{PT}$ symmetry operator and then verify $\mathcal{PT}$ symmetry of the time-evolution operator of the one-dimensional non-unitary quantum walk[5]. Taking this result into account, we then study Floquet topological phases of the $\mathcal{PT}$ symmetric non-unitary quantum walk[6]. We numerically observe that, by introducing position dependent parameters into the system by keeping $\mathcal{PT}$ symmetry of the time-evolution operator, localized states with zero and π quasienergies appear near the interface where the topological number varies from a value to the other one. We further confirm that the number of the localized states agree with the bulk-edge correspondence. We also find that only localized eigen states originating to Floquet topological phases break $\mathcal{PT}$ symmetry in the proper setup. This provides a way to observe highly intense probabilities of localized states originating to Floquet topological phases of the one-dimensional non-unitary quantum walk in actual experimental setups.

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