Experimental observation of topologically protected bound states with vanishing Chern numbers in two dimensional quantum walk

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Abstract

Quantum walks (QWs) provide a powerful tool as a quantum simulator to study topological phases. However, some interesting topological phenomena in the two dimensional (2D) QW that do not exist in the one dimensional case, e.g., the edge-state-enhanced transport, have not been demonstrated experimentally. Here we have observed 2D topological bound states with vanishing Chern numbers and confirmed the robustness of these bound states with respect to perturbations and disorder, which go beyond what has been known in static systems and are unique to periodically driven systems. Our studies open up an avenue to explore topological properties in multidimensional QWs.

Here we construct a new 2D QW platform in which spatial positions and orbital angular momentum (OAM) states of light serves as two distinct degrees of freedom in the position space of 2D QWs. One step operator of the 2D QW is described as $U = T_y R(\theta_2) T_x R(\theta_1)$,where $R\left(\theta_{1(2)}\right) = e^{-i\theta_{1(2)}\sigma_y/2}\sigma_z$ is a coin operator. In the experiment, we employ a customized q-plate involving multiple patterns to match the parallel multi-beams produced by beam displacers (BDs), then construct inhomogeneous regions in 2D QWs by applying different coin operators to the beams in different spatial positions. Topologically protected bound states can be formed at the boundary between these inhomogeneous regions. The advantage of fully control of each lattice site in the 2D QW makes our experimental platform suitable for topological study. As shown in Fig. 1, we have observed 2D topological edge states with vanishing Chern numbers and confirmed the robustness of these edge states against small perturbations and disorder.

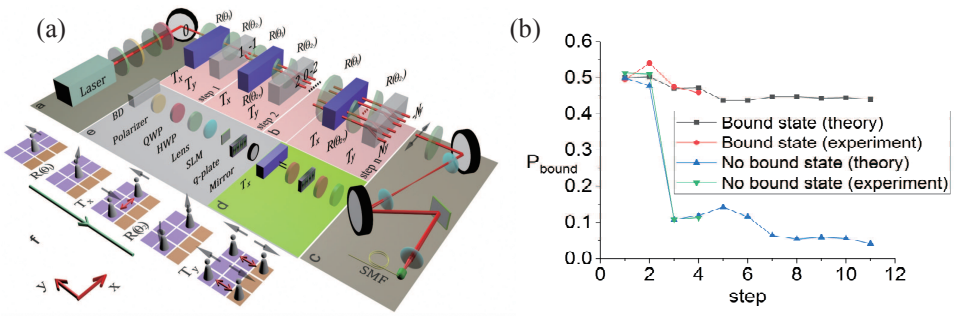

Figure 1: (a)Experimental scheme for 2D QWs.(b)The localized probability at the boundary in 2D QWs with step.

In summary, we have constructed a new 2D QW experimental platform using spatial positions and OAM of light. We have observed 2D topological edge states with vanishing Chern numbers and confirmed the robustness of these edge states against small perturbations and disorder. Such a phenomenon goes beyond what has been known in static systems and is unique to periodically driven systems. In addition, our experimental setup can also be used as a powerful platform to study other topics including energy transport in the 2D QW and so on [2,3].

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