Observing The Topological Invariant of Bloch Bands Using Quantum Walks in Superconducting Circuits

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The direct measurement of topological invariants in both engineered and naturally occurring quantum materials is a key step in classifying quantum phases of matter. Here we motivate a toolbox [1] based on time-dependent quantum walks as a method to digitally simulate single-particle topological band structures. Using a superconducting qubit dispersively coupled to a microwave cavity, we implement two classes of split-step quantum walks and directly measure the topological invariant (winding number) associated with each. The measurement relies upon interference between two components of a cavity Schrödinger cat state and highlights a novel refocusing technique which allows for the direct implementation of a digital version of Bloch oscillations. Our scheme can readily be extended to higher dimensions, whereby quantum walk-based simulations can probe topological phases ranging from the quantum spin Hall effect to the Hopf insulator.

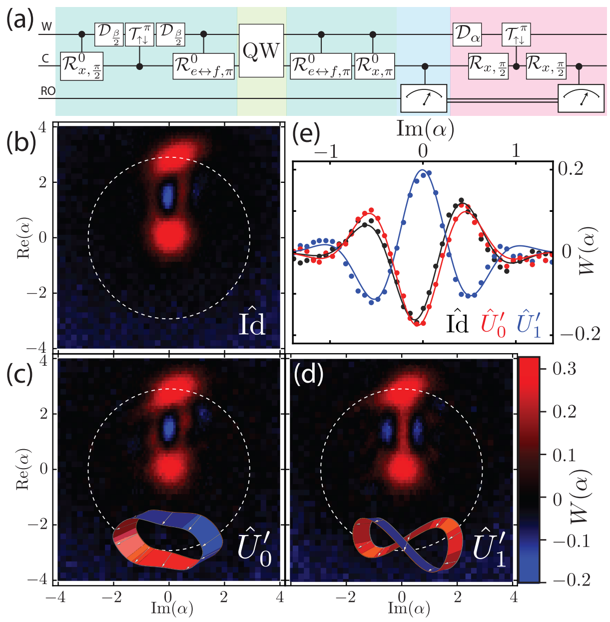

Figure 1. Winding number measurement via direct Wigner tomography of refocused Schrdinger cat states. (a) Protocol for measuring topology via a Bloch oscillating quantum walk. Wigner tomography of (b) the cat undergoing no quantum walk, (c) the cat after undergoing the trivial walk, and (d) the cat after undergoing the topological walk. The Berry phase — captured by the phase difference between the topological and the trivial walks — is $1.05\pi \pm 0.06\pi$ in experiment, consistent with the theoretical expectations of π.

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