Quantum Hall Physics with Quantum Walks in a Synthetic Magnetic Field

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Résumé

Simulation of quantum transport with discrete-time quantum walks (DTQWs) has been realized in various experiments including ultra-cold neutral atoms in optical lattices [1]. For example, the behavior of charged particles in a periodic potential subject to an external electric field has been simulated with neutral atoms in spin-dependent one-dimensional optical lattices where acceleration of the lattice corresponds to an electric field acting on charged particles [2].

Here, we propose a scheme based on DTQWs to recreate integer quantum Hall (IQH) physics with pseudo-spin-1/2 particles. Quantum walks are particularly suited to study the limit of strong fields, that is, when the magnetic flux per plaquette becomes comparable with the magnetic flux quantum. We compute the bulk topological invariants, i.e. the Chern numbers of the bands, of DTQWs in a synthetic magnetic field. Further, we discuss an experimental proposal based on realistic experimental conditions, which uses neutral atoms to implement synthetic magnetic fields in a DTQW. Our experimental proposal is especially advantageous as it permits to "dial" any synthetic magnetic field landscape, including those with sharp spatial boundaries, along which matter waves are expected to flow without dissipation into the bulk. Simulating IQH physics is an important step in view of experimental investigations of topological phases with interacting atoms.

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