The Quantum Spin Hall and Quantum Anomalous Hall Effects in a Two-Dimensional Decorated Lattice with Spin-Orbit Coupling and Staggered Potential

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In this contribution, we present quantum spin Hall effect (QSHE) and quantum anomalous Hall effect (QAHE) regimes for a decorated lattice with spin-orbit coupling and staggered potential. To obtain this, we employ numerical calculation of entanglement spectrum and trace index.

QSHE and QAHE are two of many of recently discovered types of phenomena analogous to the quantum Hall effect, occurring in the absence of an external magnetic field. They can be found in topological materials, which have recently been one of the most rapidly developing subjects in the field of condensed matter physics.

We investigate a two-dimensional decorated lattice with the spin-orbit interaction subject to a staggered potential. The decorated lattice itself characterizes with a flat energy band and highly degenerate ground state at half filling. To bring the system to the regime of the QAHE or QSHE we need to remove the ground state degeneracy, keeping the energy band dispersionless. This is done by introducing the staggered potential [1].

To study the topological properties of the system in question, we employ tools associated with the quantum entanglement. Hereby, we focus on two of the entanglement-releated quantities, namely the entanglement spectrum [2] and the trace index [3]. We perform a spatial division of the discussed system into two parts and investigate the properties of the reduced density matrix of one of the subsystems, which corresponds to the entanglement Hamiltonian between these two parts and, therefore, describes the properties of the entanglement between them. Both of the quantities utilized by us can be calculated from this reduced density matrix.

From the entanglement spectrum, we get insight into low-energy excitations of the entanglement Hamiltonian. The trace index is equivalent to the Chern number. Using these information, we have determined the ranges of the spin-orbit interaction strength and staggered potential values, for which the QSHE and QAHE phases appear.

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[3] A. Alexandradinata, Taylor L. Hughes, and B. Andrei Bernevig, *Phys. Rev. B* **84**, 195103 (2011).