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Floquet engineering with ultracold fermions: From Haldane's model of topological bands to spin-dependent lattices

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Periodically driving a system of ultracold fermionic atoms in an optical lattice allows for implementing a large variety of effective Hamiltonians through Floquet engineering. Using this concept we realize the Haldane model which is a fundamental example of a Hamiltonian exhibiting topologically distinct phases of matter. By loading non-interacting degenerate fermions in a periodically modulated honeycomb lattice we can implement and characterize the topological band structure. We explore the resulting Berry-curvatures of the lowest band and map out topological phase transitions connecting distinct regimes.

Such a technique may be extended to also address internal degrees of freedom. By periodically modulating a magnetic field gradient we tune the relative amplitude and sign of the tunneling for different internal states. Thereby we experimentally realize spin-dependent effective Hamiltonians where one state can be pinned to the lattice, while the other remains itinerant. For each spin state, the differing band structure can be characterized either by measuring the expansion of an atomic cloud in the lattice, or by a measurement of the effective mass through dipole oscillations. Furthermore we use the tunability of ultracold atoms to investigate the role of interactions.