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Synthetic gauge fields with ultracold atoms in periodically-driven lattices

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Ultracold atoms in optical lattices are powerful experimental platforms to study a variety of phenomena ranging from condensed-matter to statistical physics. Recently, a promising new direction was opened by the successful realization of paradigmatic topological condensed matter models, in particular the Hofstadter and the Haldane model. Topological states of matter exhibit unique conductivity properties, which are particularly robust against perturbations. One of the most prominent examples are quantum Hall insulators. I will introduce some of the most common methods used to generate topological band structures in ultracold atoms based on Floquet engineering. This method relies on periodic modulation of the systems parameters to emulate the properties of an otherwise inaccessible static system. The successful implementation of these techniques led to the direct observation of bulk topological properties and chiral currents in optical lattices with synthetic gauge fields. Floquet engineering can further been employed to simulate density-dependent gauge fields or even complete gauge theories, which require an interaction between matter and gauge fields. One example is the realization of Z_2 lattice gauge theories, which play an important role in condensed matter physics and quantum computation. Recently, we have implemented such a model with a two-component mixture of ultracold bosons in a double-well potential $-$ the basic building block of Z_2 lattice gauge theories. The rich properties of Floquet systems, however, go well beyond those of their static counterparts. The quasienergy spectrum can have a non-trivial winding number, which leads to the appearance of anomalous chiral edge modes in the quasienergy spectrum. For instance, an anomalous Floquet insulator with topologically trivial bulk bands can present topologically protected chiral edge modes. These intriguing phases can be directly observed, e.g., in periodically driven honeycomb lattices.