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*Artificial Gauge Fields with Ultracold Atoms in Optical Lattices*

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 research direction was opened by the successful realization of two paradigmatic topological condensed matter models, the Hofstadter and the Haldane model. Topological states of matter exhibit unique conductivity properties, which are particularly robust against perturbations. This was discovered in the context of the integer quantum Hall effect, where a two-dimensional electron gas under extreme conditions, i.e. low temperatures and strong magnetic fields, exhibits a quantized conductivity, which is rooted in the topological properties of the energy bands.

Investigating related phenomena with charge-neutral atoms required the development of novel experimental techniques to mimic the behavior of charged particles in magnetic fields. I will briefly introduce some of the most common methods based on periodic driving of the system's parameters, which led to the successful generation of artificial magnetic fields in optical lattices and direct observations of the non-trivial topological properties of the engineered energy bands. Extending these techniques to the many-body regime in order to investigate the exotic properties of topological many-body phases, such as the fractional Quantum Hall effect, is currently an active field of research.

Gauge theories are fundamental to our understanding of physics at all scales, ranging from condensed-matter physics to high-energy physics. To realize full gauge theories a key ingredient is missing in current experimental implementations, i.e. there is no interaction between the atoms and the internal degrees of freedom of the gauge-field. I will present recent results, where we have used a combination of periodic modulation and strong interactions to realize a minimal building block of $Z_2$ lattice gauge theories with a mixture of ultracold bosonic atoms in an optical double-well potential.