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Artificial gauge fields and topology with ultracold atoms in optical lattices

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Many intriguing condensed matter phenomena such as the integer and fractional quantum Hall effect arise due to the non-trivial topological properties of the underlying system. Synthetic materials that consist of ultracold neutral atoms confined in crystal-like structures using laser beams have the potential to simulate and address the complex questions that arise in this context. In this talk I report on the experimental realization of extremely strong artificial magnetic fields based on laser-assisted tunneling which give rise to topological energy bands. Their properties are characterized by topological invariants - the Chern numbers - which are at the origin of the integer quantum Hall effect. In particular we were able to realize the Hofstadter model for an effective flux 1/4 and determined the Chern number of the lowest energy band through a direct measurement of bulk topological currents. These experimental results pave the way for future studies of interacting topological systems with ultracold atoms in optical lattices.