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Creation of effective magnetic fields in optical lattices: the Hofstadter butterfly for cold neutral atoms

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Abstract

We investigate the dynamics of neutral atoms in a 2D optical lattice which traps two distinct internal states of the atoms in different columns. Two Raman lasers are used to coherently transfer atoms from one internal state to the other, thereby causing hopping between the different columns. By adjusting the laser parameters appropriately we can induce a non-vanishing phase of particles moving along a closed path on the lattice. This phase is proportional to the enclosed area and we thus simulate a magnetic flux through the lattice. This set-up is described by a Hamiltonian identical to the one for electrons on a lattice subject to a magnetic field and thus allows us to study this equivalent situation under very well defined controllable conditions. We consider the limiting case of huge magnetic fields—which is not experimentally accessible for electrons in metals—where a fractal band structure, the Hofstadter butterfly, characterizes the system.

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