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Experimental realization of density-dependent Peierls phases to couple dynamical gauge fields to matter FREDERIK GOERG, KILIAN SANDHOLZER, JOAQUIN MINGUZZI, REMI DESBUQUOIS, KONRAD VIEBAHN, ANNE-SOPHIE WALTER, MICHAEL MESSER, TILMAN ESSLINGER, Institute for Quantum Electronics, ETH Zurich — The coupling between gauge and matter fields plays an important role in many models of high-energy and condensed matter physics. In these models, the gauge fields are dynamical degrees of freedom in the sense that they are influenced by the spatial configuration and motion of the matter field. So far, synthetic magnetic fields for ultracold atoms in optical lattices were intrinsically classical, as they did not feature any back-action from the atoms. We realize the fundamental ingredient for a density-dependent gauge field by engineering non-trivial Peierls phases that depend on the site occupation of fermions in a Hubbard dimer. Our method relies on breaking time-reversal symmetry by driving the optical lattice simultaneously at two frequencies which are resonant with the onsite interaction energy. We demonstrate a technique to quantify the amplitude of the resulting density-assisted tunneling matrix element and to directly measure its Peierls phase with respect to the single-particle hopping. The tunnel coupling features two distinct regimes which can be characterized by a Z2-invariant. Moreover, we provide a full tomography of the winding structure of the Peierls phase around a Dirac point that appears in the driving parameter space. Our experiments constitute the first step towards the quantum simulation of intractable problems in lattice gauge theories such as quantum electro- or chromodynamics.

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