Bloch-Zener oscillations as a probe of Dirac points merging in artificial graphene

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By varying band parameters, Dirac points can be manipulated and merged at a topological transition towards a gapped phase. For example, Dirac points in graphene can be manipulated by applying stress to the crystal. However the topological merging transition is unreachable as it would require unphysically large deformations of the graphene sheet.

Recently, an experiment conducted in ETH Zürich realized a kind of “artificial graphene” by loading ultracold fermions in a tunable brick-wall optical lattice [1]. Under a constant force, a Fermi sea initially in the lower band can perform Bloch oscillations and may Zener tunnel to the upper band mostly at the location of the Dirac points. Bloch oscillations and Landau-Zener tunneling were used in this experiment to detect the presence/absence of Dirac points as a function of optical lattice parameters. A vanishing tunneling probability was interpreted as a disappearance of Dirac points due to a merging transition.

We propose a simple anisotropic square tight-binding hamiltonian as a minimal model to describe such an experiment [2]. At low energy it maps onto a so called universal hamiltonian [3] describing the vicinity of the merging transition. We compute the corresponding tunneling probability and obtained a very good agreement with the experiment. In addition, we study Stückelberg oscillations in such a system and show how they could be observed in a strictly 2D gas. We also discuss the merging point, at which a semi-Dirac spectrum (linear in one direction, quadratic in the other) is expected and should lead to new physics.

References

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