Wannier-Stark states and topological phase transitions in tilted two-dimensional bipartite lattices

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By definition Wannier-Stark states are eigenstates of a quantum particle in a tilted (biased) lattice. These states and the related phenomenon of Bloch oscillations (which are a dynamical aspect of the problem) are well understood in one dimension [1] but their extension into two dimensions [2] continues to surprise researches. In my contribution I summarize main properties of two-dimensional Wannier-Stark states, focusing on topological phase transitions in the tilted brick-wall and honeycomb lattices [3]. As as the tilt is varied the system shows a sequence of topological phase transitions, which can be easily detected in laboratory experiments with cold atoms in stationary (no heating!) optical lattices by observing atomic Bloch oscillations or with light in photonic crystals by observing the edge states.

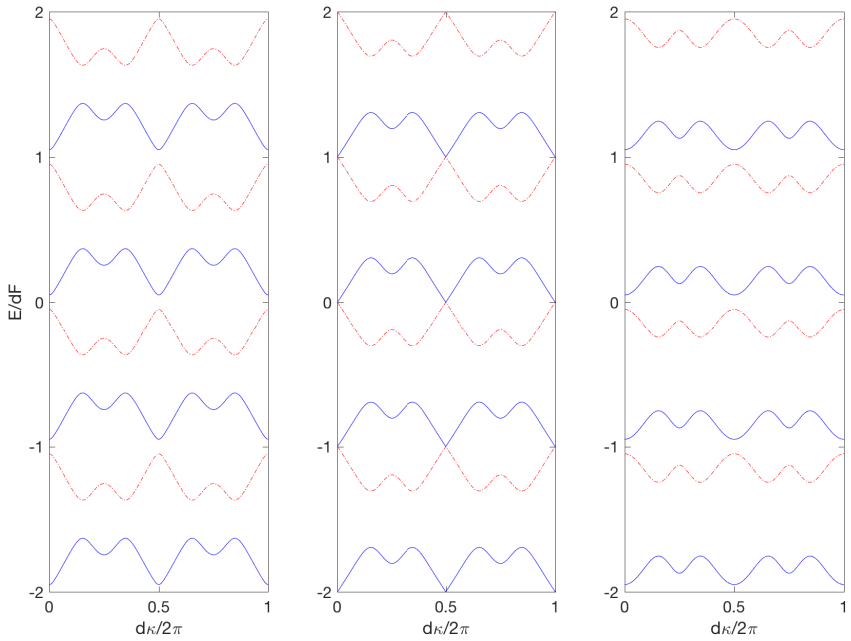

FIG. 1: Wannier-Stark ladder of energy bands in the brick-wall lattice tilted along its primary axis for three slightly different values of the tilt. The middle panel refers to a critical value of the tilt where the topological invariant (winding number, an analogue of the Zak phase) changes its value.

[1] D. N. Maksimov, E. N. Bulgakov, and A. R. Kolovsky, Wannier-Stark states in double-periodic lattices. I. One-dimensional lattices, Phys. Rev. A **91**, 053631 (2015).

[2] D. N. Maksimov, E. N. Bulgakov, and A. R. Kolovsky, Wannier-Stark states in double-periodic lattices. II. Two-dimensional lattices, Phys. Rev. A **91**, 053632 (2015).

[3] A.R.Kolovsky, Topological phase transitions in tilted optical lattices, Phys. Rev. A, to appear (2018).