

Observation of Floquet-Bloch states in Dirac materials

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Floquet engineering is a novel method of manipulating quantum phases of matter via periodic driving. It has successfully been utilized in different platforms ranging from photonic systems to optical lattice of ultracold atoms. In solids, light can be used as the periodic drive via coherent light-matter interaction. This leads to hybridization of Bloch electrons with photons resulting in replica bands known as Floquet-Bloch states. In this talk, I will discuss direct observation of Floquet-Bloch states in topological insulators and graphene. I will first review the original discovery of Floquet-Bloch states in a topological insulator. Since then, their manifestations have been seen in a number of other experiments. By engineering the electronic band structure using Floquet-Bloch states, various exotic phase transitions have been predicted to occur. To realize these phases, it is necessary to better understand the nature of Floquet-Bloch states in different materials. However, direct energy and momentum resolved observation of these states is still limited to only few material systems. I will then report the recent direct observation of Floquet-Bloch states in monolayer epitaxial graphene¹ which was the first proposed material platform for Floquet engineering. By using time- and angle-resolved photoemission spectroscopy (trARPES) with mid-infrared (mid-IR) pump excitation, we detected replicas of the Dirac cone. Pump polarization dependence of these replica bands unequivocally shows that they originate from the scattering between Floquet-Bloch states and photon-dressed free-electron-like photoemission final states, called Volkov states. Beyond graphene, our method can potentially be used to directly observe Floquet-Bloch states in other systems paving the way for Floquet engineering in a wide range of quantum materials.

Keywords: Floquet Engineering, Optical control, graphene, time- and angle-resolved photoemission spectroscopy

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¹ Dongsung Choi, Masataka Mogi, Umberto De Giovannini, Doron Azouary, Baiqing Lv, Yifan Su, Hannes Hübener, Angel Rubio & Nuh Gedik, “*Observation of Floquet–Bloch states in monolayer graphene*”, Nature Physics (2025)