Geometry and Topology in Strong Field Dynamics of Dirac Electrons

Takashi Oka

Institute of Solid State Physics, The University of Tokyo, Chiba, 277-8581, Japan
Max Planck Institute for the Physics of Complex Systems, Dresden, 01187, Germany
Max Planck Institute for Chemical Physics of Solids, Dresden, 01187, Germany

*E-mail: oka@issp.u-tokyo.ac.jp

Geometry and topology play a prominent role in modern condensed matter physics. Exotic quantum phenomena such as quantum Hall effect and dissipationless edge states may appear as a consequence of a non-trivial topology of the single body bands. On the other hand, in nonequilibrium physics, the role of geometry and topology is still not fully understood. Electron dynamics in Dirac semimetals induced by laser fields are a natural testbed to study their role. Experimentally, high-intensity-phase-locked lasers enable us to study the quantum coherent dynamics using high harmonic generation. The dynamics depend strongly on the frequency, polarization, as well as the strength of the laser electric field. In THz fields, electrons reach a steady-state with a nonthermal distribution as a consequence of the balance between the driving force and relaxation (Fig.1(a))[1]. When the field becomes stronger, quantum effects start to kick in. The first relevant process is quantum tunneling, where electron-hole carriers are pair created (Fig.1(b)). Tunneling is strongly affected by geometric effects [2]. In higher frequency laser fields, the electrons feel the time-periodic effect, and we can describe their properties using Floquet states. Weyl electrons describe the Floquet state of 3D Dirac electrons. Topological effects, such as edge and Hall transport, follow [3].

* This work has been done in collaboration with Shintaro Takayoshi, Jianda Wu, Zhe Wang, Renato Dantes, and Piotr Surowka.

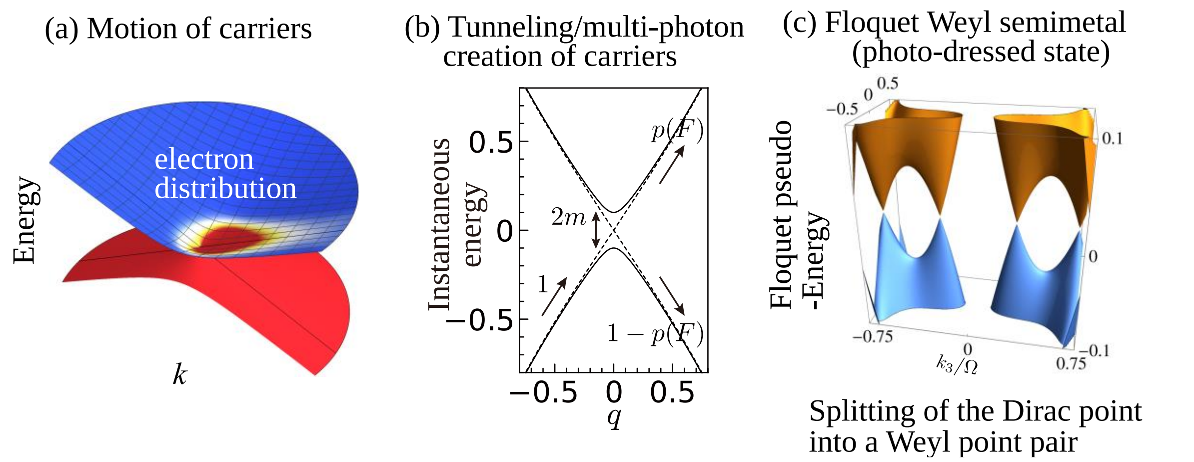

Figure 1: (a) Non-thermal carrier dynamics leading to a shift and distortion of the electron distribution, **(b)** Quantum tunnelling and multi-photon creation of electron-hole pairs, **(c)** Floquet quasi-energy bands formed by electrons being dressed by the photons. The Dirac point splits into two Weyl points.

References:

[1] S. Kovalev et al. “Non-perturbative high-harmonic generation in the three-dimensional Dirac semimetal CdAs”, Nature Communications 11, 2451 (2020).
[2] S. Takayoshi, J. Wu, and T. Oka, *arXiv:2005.01755*.
[3] L. Bucciantini, S. Roy, S. Kitamura, and T. Oka, “Emergent Weyl nodes and Fermi arcs in a Floquet Weyl semimetal”, Physical Review **B 96**, 041126 (2017).