Morphology change of Dirac cones under intense electromagnetic fields

Yosuke Kayanuma [1] and Keiji Saito[2]

[1]Materials and Structures Laboratory, Tokyo Institute of Technology, Japan
[2] Department of Physics, Keio University, Japan
Corresponding Author: kayanuma.y.aa@m.titech.ac.jp

Peculiar optical as well as transport properties of Dirac electrons in two-dimensional systems such as graphene and surface states of topological insulators are attracting intense attention. Here we present a comprehensive theoretical study of the coherent dynamics of Dirac electrons driven by external electromagnetic fields. Assuming the long wave-length limit, the dimensionless Hamiltonian for electrons in the vicinity of a Dirac point is written, by the Pauli matrices σ_x and σ_z, as

$$H(t)=\left(p_x-\frac{e}{c}A_x(t)\right)\sigma_x+\left(p_z-\frac{e}{c}A_z(t)\right)\sigma_z\ , \qquad (1)$$

where p_x and p_z are momentums of the electron, $A_x(t)$ and $A_z(t)$ are the vector potentials, which are set as $eA_x(t)/c=\beta\sin\omega t$ and $eA_z(t)/c=\alpha\cos\omega t$. The coherent morphological changes of the Dirac cone are clarified from the topological viewpoint for the circular $(\alpha=\beta)$, elliptic $(\alpha>\beta)$ and linear $(\beta=0)$ polarization of light. According to the choice of values of α, β and ω, the shape of the Dirac cone changes dramatically to Dirac wedge (a zero-gap line), Dirac trough (a pair of trough-like bands) and normal insulator with a Dirac gap. In Fig. 1, an example of the two-dimensional plot of the effective gap is shown for the Dirac wedge mode ($\beta=0,\ 2\alpha/\omega=2.4$) calculated by the Floquet theory. Proposals for experimental observation will also be discussed.

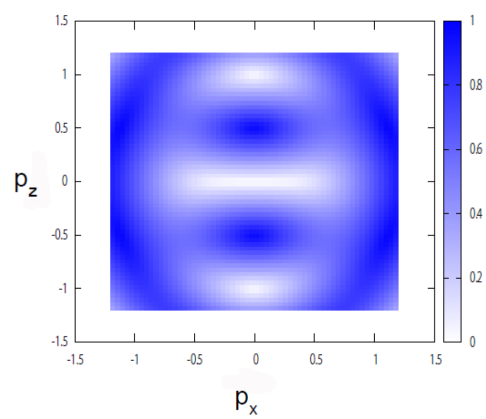

Figure 1 Band gap for the case of Dirac wedge mode