Generalized Hamiltonian for Kekulé graphene and the emergence of valley-cooperative Klein tunnelling

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We introduce a generalized Hamiltonian describing not only all topological phases observed experimentally in Kekulé graphene (KekGr) but predicting also new ones. These phases show features like a quadratic band crossing point, valley splitting, or the crossing of conduction bands, typically induced by Rashba spin-orbit interactions or Zeeman fields. The electrons in KekGr behave as Dirac fermions and follow pseudo-relativistic dispersion relations with Fermi velocities, rest masses, and valley-dependent self-gating. Transitions between the topological phases can be induced by tuning these parameters. The model is applied to study the current flow in KekGr pn junctions evidencing a novel cooperative transport phenomenon, where Klein tunneling goes along with a valley flip. These junctions act as perfect filters and polarizers of massive Dirac fermions, which are the essential devices for valleytronics. The plethora of different topological phases in KekGr may also help to establish phenomena from spintronics.

Figures

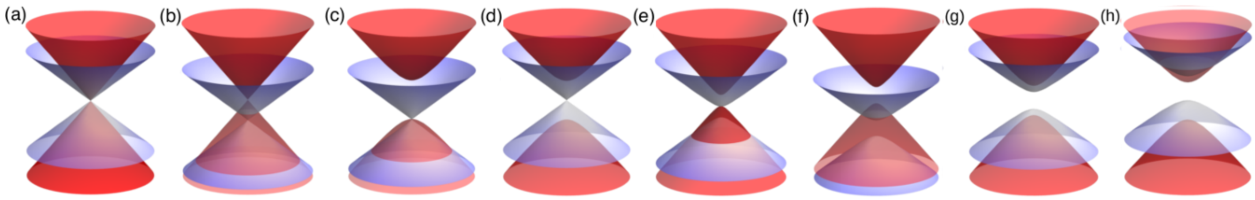

Figure 1: Topological phases of Kekulé graphene (KekGr). (a) and (b) Massless Dirac fermions in both valleys. (c) and (d) Chiral symmetry breaking in a single valley, where electrons behave as massless and massive Dirac fermions. (e) and (f) Quadratic band crossing point and valley-orbit coupling, respectively. (g) Zeeman-like effect. (h) Crossing of conduction bands.

References

[1] Santiago Galván y García, Thomas Stegmann and Yonatan Betancur-Ocampo, Generalized Hamiltonnian for Kekulé graphene and the emergence of valley-cooperative Klein tunneling, arXiv: 2111:06001