Berry's Phase and Giant Non-Reciprocity in Graphene Quantum Dots

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Abstract

Recently, nanoscale pn-junction rings have been introduced as a vehicle for coherent control of electronic states in graphene [1]. Confined states in such ring-shaped electron resonators arise due to constructive interference of electronic waves incident at the pn junction at oblique angles and inward-reflected from the ring. Contrary to confined electronic states in conventional quantum dots, Dirac electrons are characterized by a non-trivial Berry's phase. Here we show [2] that the graphene quantum dot energy levels are strongly sensitive to the Berry's phase. In particular, we predict that the Berry's phase can induce a giant spectral non-reciprocity arising in weak magnetic fields. The effect is manifested in anomalously large splittings of the resonances, degenerate at B=0 due to time reversal symmetry, and disappears for gapped graphene. This non-reciprocity effect overwhelms the conventional orbital and spin-induced non-reciprocity. The predicted giant non-reciprocity is readily accessible by Faraday and Kerr optical rotation measurements as well as by scanning tunneling spectroscopy.

References

[1] Zhao, et al., Science 348,672(2015).
[2] Rodriguez-Nieva, et al., arXiv:1508.06609.

Figures

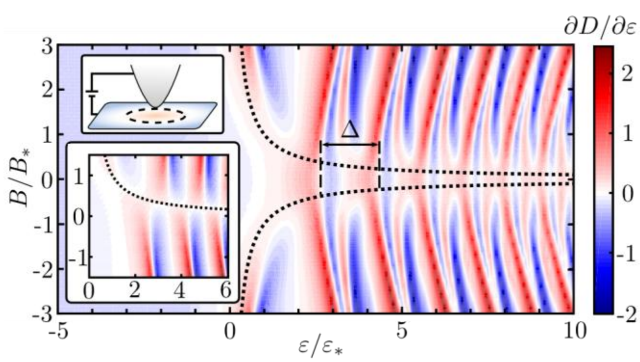

Figure 1. Spectral maps showing splitting of periodic time-reversed WGM resonances under weak magnetic fields *B* in a graphene quantum dot. Here ε is the electron energy and Δ indicates the resonance period at zero magnetic fields. Plotted with dotted lines is the critical magnetic field for resonance splitting to occur. The Dirac equation in scalar potentials defines characteristic units for energy, ε_* , magnetic field, B_* , and distance, r_* . To enhance spectral features, we plot the derivative of the local Density of States at the center of the quantum dot.