Electrostatically induced nanostructures in gapped bilayer graphene

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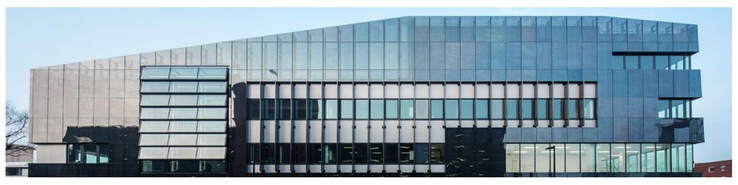

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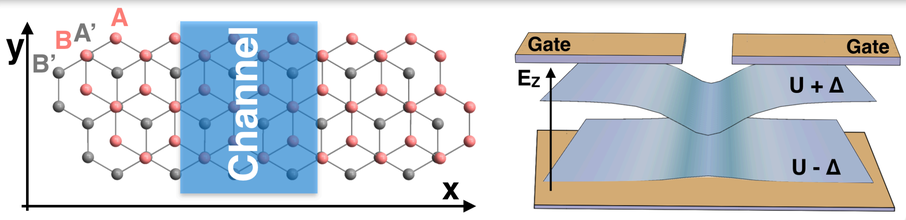
Abstract

The spectrum of subbands in an electrostatically defined quantum wire in gapped BLG manifests the minivalley structure and Berry curvature via the associated magnetic moment of the states in the low-energy bands. These features determine the degeneracies of the low-energy minibands and their valley splitting, which develops linearly in a weak magnetic field. Magneto-conductance reflects such degeneracies in the heights of the first conductance steps which develop upon the increase of the channel doping: $8e^2/h$ steps in a wide channel in BLG with a large gap, $4e^2/h$ steps in narrow channels, all splitting into a staircase of $2e^2/h$ steps upon lifting valley degeneracy by a magnetic field B [1].

Conduction channel in BLG

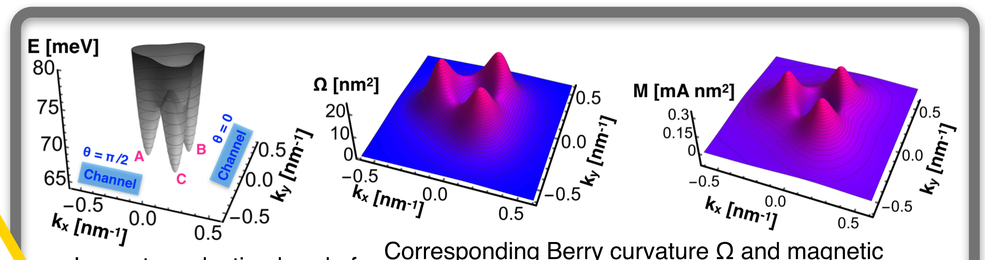


- Electrostatic confinement of electrons in a one-dimensional channel in gapped Bernal stacked BLG through dual (top and bottom) gating.
- Model: a confinement potential U(x) and a spatially modulated gap Δ(x) in the four-band Hamiltonian of BLG:

$$U(x) = \frac{U_0}{\cosh\frac{x}{L}} \qquad \Delta(x) = \Delta_0 - \frac{\beta\Delta_0}{\cosh\frac{x}{L}}$$

How do minivalleys and Berry curvature influence channels in gapped BLG ?

Minivalleys and Berry curvature in BLG

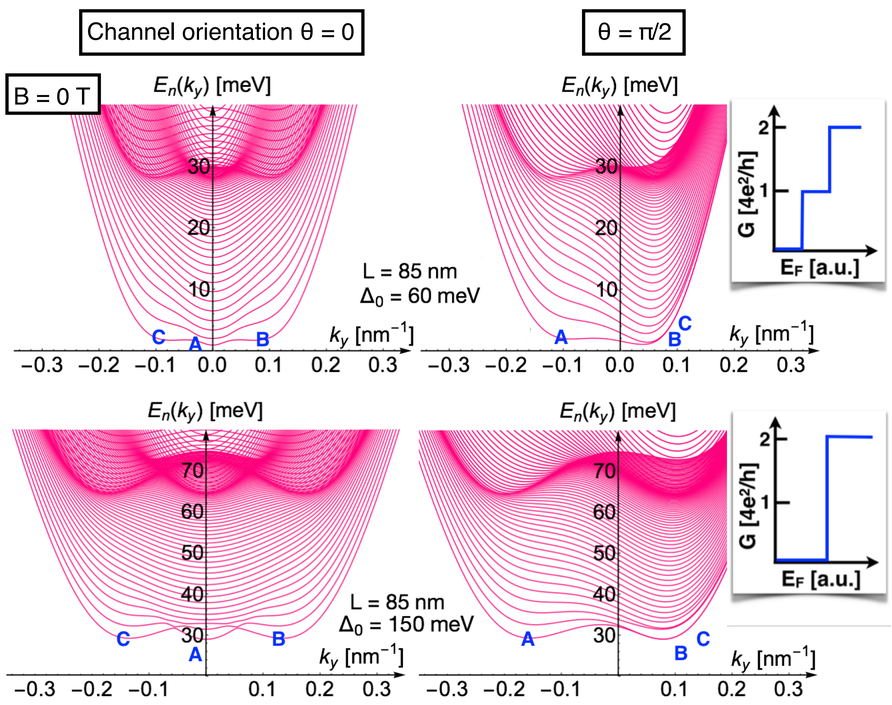


Lowest conduction band of gapped BLG around K⁻

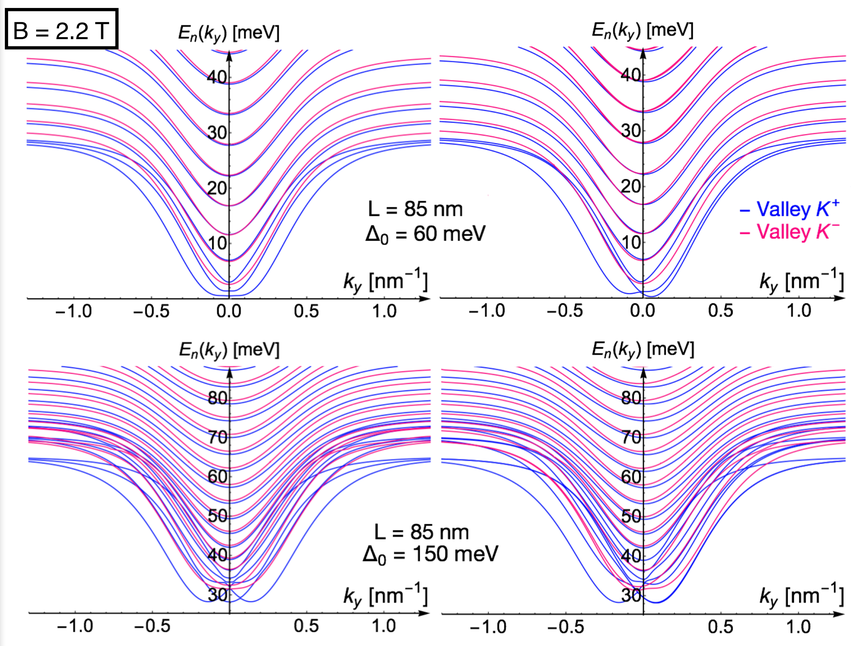
Corresponding Berry curvature Ω and magnetic moment M. Both carry opposite sign in the opposite valley

- Lowest conduction band of gapped BLG in the presence of trigonal warping features three minivalleys around each K point
- Both the Berry curvature, Ω, and the corresponding magnetic moment, M, are non-zero within the minivalleys

Channel spectra

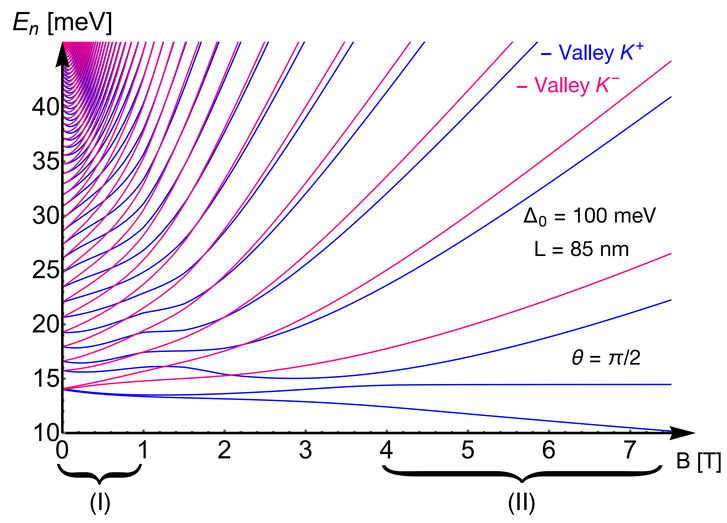


The minima of the subbands reflect the minivalley structure of BLG. Counting numbers of modes leads to predictions for the conduction, G, through the channel

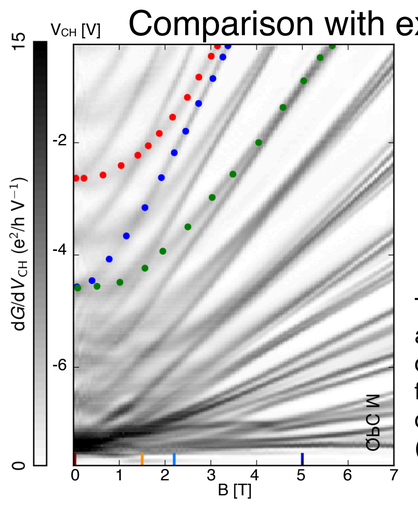


Valley symmetry is broken in the presence of a gap and a nonzero magnetic field

Subband edges in a magnetic field



Comparison with experiment:



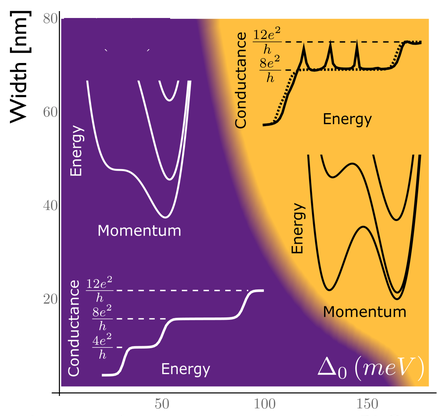
Transconductance as a function of the channel voltage V_{CH} for different values of the magnetic field (Figure from Ref [2])

(I) Low field regime: The states carry Berry curvature and a corresponding finite magnetic moment, M, which couples linearly to a magnetic field. The sign of M is opposite in the two valleys. ➡ linear in magnetic field valley splitting $\delta E_{K^\pm} = -2|M|B$

(II) High field regime: The bands develop into the Landau Levels of gapped BLG

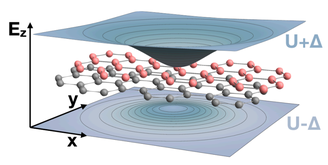
Outlook

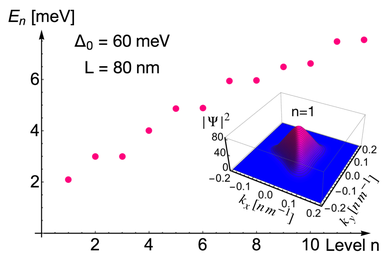
- Non-adiabatic transport in the semi-metallic (band-inverted) wires: Resonances due to scattering



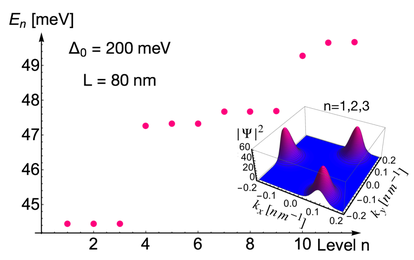
Phase diagram of quantum transport in a BLG wire [3]

- Level structure and wave functions of quantum dots in gapped BLG





- Small Δ_0: Duplets, related to angular momentum



- Large Δ_0: Triplets, related to minivalleys

References

[1] A. Knothe and V. Fal'ko, PRB 98, 155435 (2018)
[2] H. Overweg, A. Knothe, V. Fal'ko, K. Ensslin, T. Ihn, et al., PRL 121, 257702 (2018)
see also: R. Kraft, R. Danneau, et al., PRL 121, 257703 (2018)
[3] T.L.M. Lane, A. Knothe and V. Fal'ko, arXiv:1904.00918

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