Robust propagating in-gap modes due to spin-orbit domain walls in graphene

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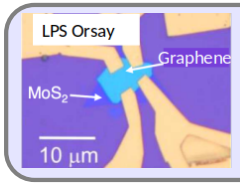


Graphene based platforms are promising for topological states design.
Substrates induce inhomogeneous SOC : Valley-Zeeman(VZ), Rashba(R), Kane-Mele(KM).

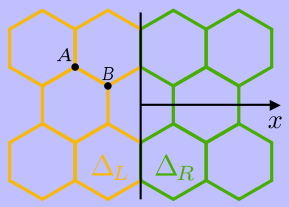
Are there topologically protected electronic states due to inhomogeneous couplings?

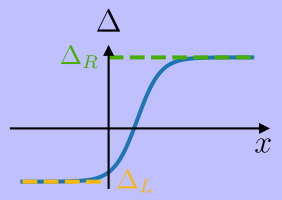
One dimensional protected states on Domain Walls (DWs), including edges. **Beyond the usual bulk-edge.**

$$H = \tau_z\sigma_x(-i\partial_x)+k_y\sigma_y+m(x)\sigma_z+\lambda_{KM}(x)\tau_z\sigma_z s_z+\lambda_{VZ}(x)\tau_z s_z+\lambda_R(x)(\tau_z\sigma_x s_y-\sigma_y s_x)$$

DW / homog.	Dirac mass	Kane-Mele SOC	Valley-Zeeman SOC	Rashba SOC
Dirac mass	2xVAL	***1*xHEL†**	∅	∅
Kane-Mele SOC	***1*xHEL†**	*2*xHEL	∅	∅
Valley-Zeeman SOC	2xVAL‡	*2*xHEL‡	X	∅
Rashba SOC	2xVAL‡	∅	***2*xVAL**	X

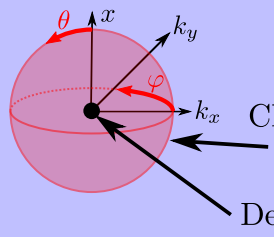
Tight binding model





Δ is a gapping term

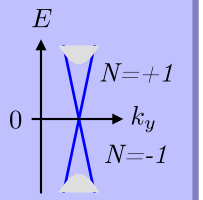
Spectral Flow theorem



$C_- = N_{chiral}$

Chern number of filled bands C_-

Degeneracy point

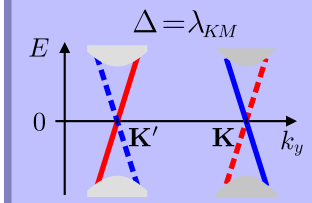


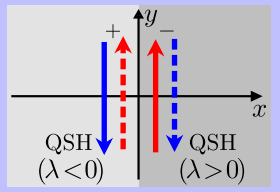
The number of chiral states leaving the valence band at the degenerate interface between two gapped hamiltonians is equal to the Chern number of the lower bands. [1]

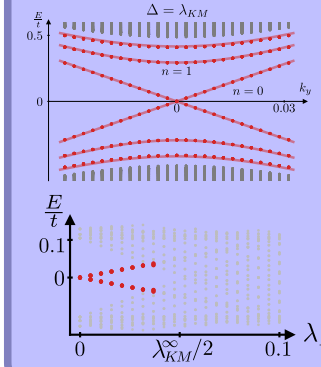
References
[1] M. Marciani and P.Delplace, Phys. Rev. A, **101**, 023827 (2020)
[2] I. Martin, Y.M. Blanter and A.F. Morpurgo, Phys. Rev. Lett. **100**, 036804 (2008)

Kane-Mele

Path 1



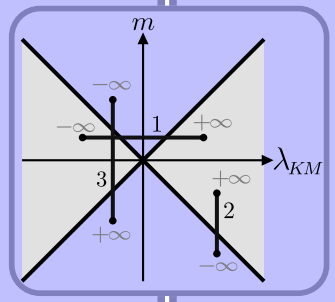




$$E_n(q_y) \quad \pm\sqrt{2v_F\frac{\lambda_0}{l}n + v_F^2 q_y^2}$$

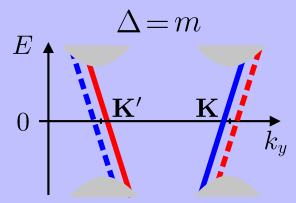
Protection by S^z symmetry.

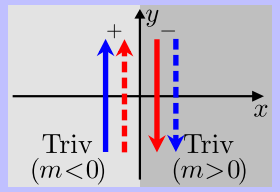
Rashba opens a gap.



Mass

Path 3



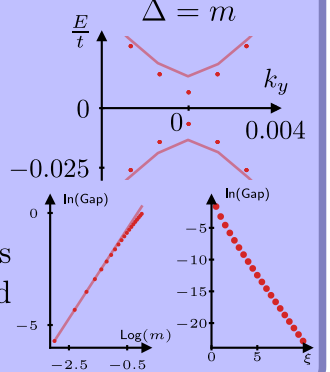


Gap

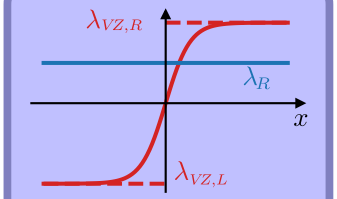
$$\frac{4m^2}{3}$$

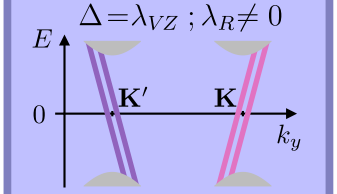
Not protected.

Intervalley scattering opens the gap tuned by DW width.

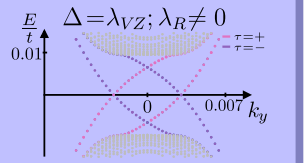


Valley-Zeeman





Protected by time-reversal symmetry. Robust modes.



Identical to spinless gated bilayer graphene [2]