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Unconventional switching using topological properties of electrons in graphene based heterostructures

Arguably the biggest challenge with graphene-based electronic switching is the lack of a band-gap. Unfortunately, forcing a band-gap through differential doping or vertical fields increases the effective mass and kills mobility. In contrast, the topology of spins/pseudospins in Dirac cone materials offers truly novel opportunities in electron dynamics, but has traditionally been touted for their impact on the on current, even while the off current remains the main challenge. We argue that the transmission of electrons across PN junctions can actually be gate-modulated significantly[1-4] due to added constraints imposed by their winding (Chern) number – for pseudospins in bulk monolayer/bilayer graphene, spins in topological insulators and Weyl semi-metals, magnetization in skyrmionic materials. Experiments show the control of Dirac fermion optics through negative index (Veselago) behavior, conductance modulation (Klein tunneling), magnetoconductance minima in Corbino discs (anti-Klein tunneling), current saturation and angle-dependent transmission (Malus' law) across bulk graphene PN junctions. Based on these data, we explain the opportunities for graphene based electronics and the material challenges along the way.

References

[1] "Spin control with a topological semi-metal", AW Ghosh, Physics 13, 28 (2020)
[2] "Graphene Transistor Based on Tunable Dirac-Fermion-Optics", PNAS 116, 6575 (2019)
[3] "Electron optics with p-n junctions in ballistic graphene", Science 353, 1522 (2016)
[4] "Manipulating Chiral transmission by Gate Geometry: Switching in Graphene with transmission gaps", ACS Nano, vol. 7 :11 , pp. 9808-9813, 2013

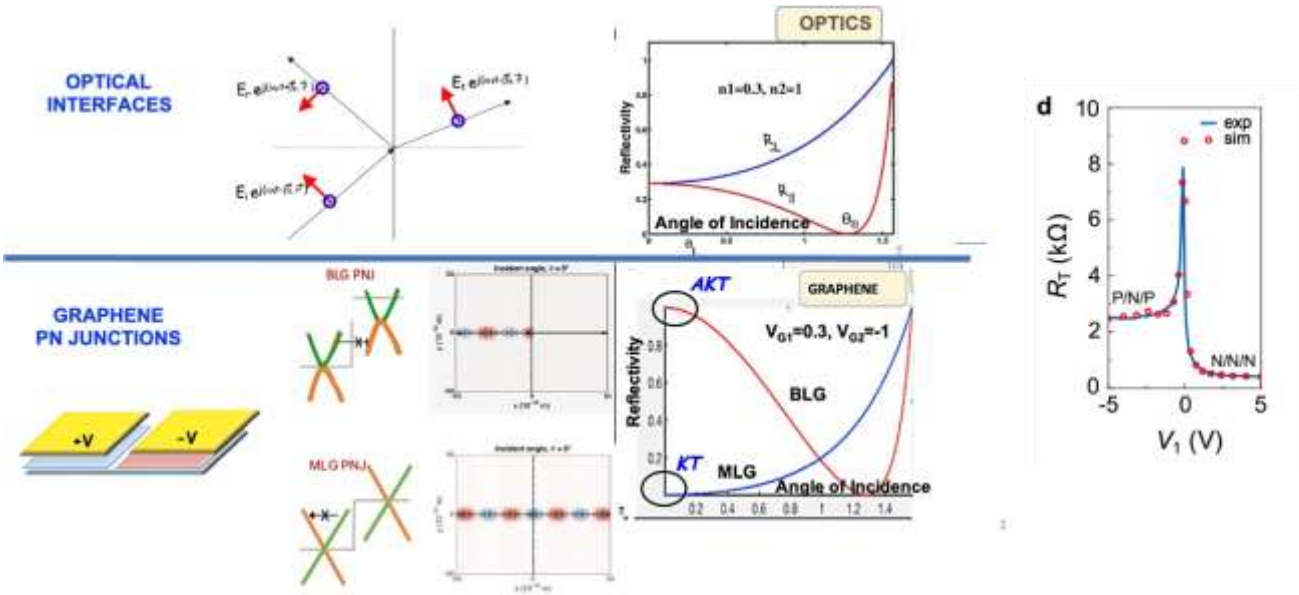

Figure 1: (Top Left) Optical Reflectivity at material interfaces at normal incidence depends on refractive index ratio at the interface. (Bottom Left) Electron reflectivity at graphene PN junctions depends only on topology of pseudospins around the Fermi circle, and is zero (Klein tunneling) for odd layer and unity (Anti-Klein tunneling) for even layers. The pinned value at normal incidence allows us to collimate electrons with a split gate and realize a *Klein tunnel transistor* with bulk graphene, based on gate-geometry alone. (Right) Experiments showing conductance modulation by gating from NNN to PNP doping in bulk graphene [2].