Pseudospintronics - Graphene transistor based on tunable topological properties of Dirac fermions

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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, beyond just their impact on mobility, especially since off current tends to pose the main challenge in switching. We argue that the transmission of electrons across PN junctions can actually be gate-modulated significantly[1-5] due to added constraints imposed by their winding (Chern) number – winding of pseudospins in bulk monolayer/bilayer graphene, spins in topological insulators and Weyl semi-metals, magnetization in skyrmionic materials. Experiments have successfully demonstrated key components along this path, including the control of trajectory through negative index (Veselago) behavior[2], control of their transmission by gate modulation of conductance (Klein tunneling)[3], magnetoconductance minima in Corbino discs (anti-Klein tunneling)[4], current saturation in bulk graphene, and angle-dependent transmission (Malus' law) across bulk graphene PN junctions[5]. Based on these data, we explain the opportunities for Dirac fermionic switches and the material challenges along the way.

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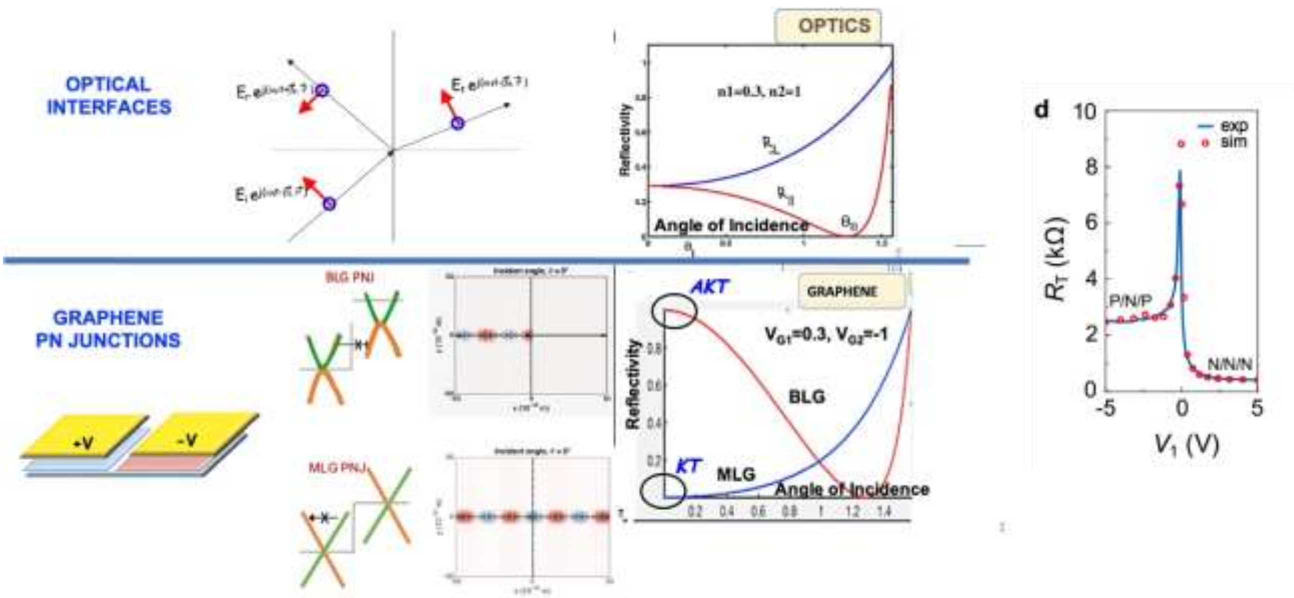

Figure 1: (Top Left) Optical Reflectivity at material interfaces at normal incidence depends on refractive index ratio at the interface. (Bottom Left) Electron reflectivity at graphene PN junctions depends only on topology of pseudospins around the Fermi circle, and is zero (Klein tunneling) for odd 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].