Optics with a twist: Switching with Dirac fermions in Graphene

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The dynamics of 2-D Dirac fermions in graphene, driven by the symmetries of their underlying pseudospins, can manifest in wavefunctions and current transmissions in ways that are fundamentally different from conventional optical interfaces. I will present numerical simulations and experimental demonstrations of several textbook optical effects mirror in graphene, albeit with a twist – specifically (i) trajectories set by *Snell's Law* but *with* ***negative index*** *of refraction* [1], (ii) angular transmission set by *Fresnel's equation* but *with* ***universal transmission*** at normal incidence, (iii) *Brewster angles set by electron pseudospin* rather than photon polarization [2], and (iv) polarizer-analyzers following *Malus' law* but *with half angles* [3]. These subtleties all arise because the photon like bandstructure comes with particle-antiparticle pairs, so that the corresponding band effective mass flips signs at a split-gated PN junction, even while electrons across differently gated graphene segments are unable to alter their group velocity. Symmetry dictates that the pseudospins (mixing coefficients of its frontier dimer pz orbitals) for an N-layer Bernally stacked graphene execute N rotations around the Fermi surface, with a fixed Berry phase Nπ and Chern number of N/2. This implies that the reflectivity at small incident angle θ across the PN junction resembles sinNθ for odd N and cos Nθ for even N, giving alternately perfect head-on transmission (Klein tunneling or KT) or head-on reflection (anti-Klein tunneling or AKT), with an angular sweet spot (Brewster angle). At the same time the higher angle electrons collimate with increasing voltage barrier (refractive index mismatch), so that by placing multiple junctions at an angle, the overall transmission can be quenched much like Malus' law in a polarizer-analyzer pair. The result is a gate tunable transmission gap that can be used to turn graphitic electrons off for bulk samples, both for digital [4, 5] and analog electronic applications [6].

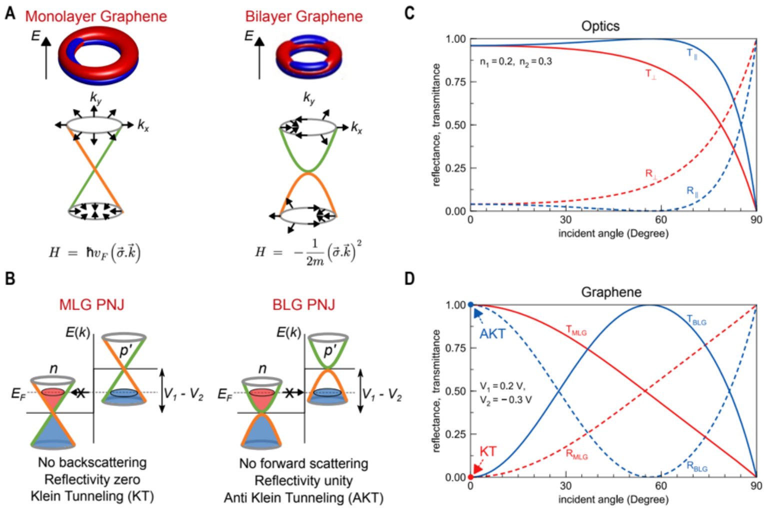

Figure 1: Electron wavefunction symmetries, their matches across a PN junction, and the resulting transmission/reflection plots, contrasting with their optical counterparts (Fresnel law).

References

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