

Optimal spin-charge interconversion in graphene by spin-pseudospin entanglement control [1]

Joaquín Medina Dueñas

Santiago Giménez de Castro, José H. García, Stephan Roche

Institut Català de Nanociència i Nanoeconologia (ICN2), Campus UAB, 08193 Bellaterra, Spain

Joaquin.medina@icn2.cat

The electrical generation of spin signals via spin-charge interconversion phenomena is of central interest for spintronics. In this context, graphene stands as a relevant platform, as its spin-orbit coupling (SOC) is tuned by proximity effects in an interface. Unique to graphene, the spin-momentum locking emerging from broken symmetry at the interface is mediated by the pseudospin degree of freedom, which stems from graphene's bipartite sublattice structure. Here, we propose an enhancement of spin-charge interconversion in graphene by controlling the intraparticle entanglement between the spin and pseudospin degrees of freedom [1]. We demonstrate that, while spin alone is not a conserved quantity in such SOC systems, a combined spin-pseudospin operator is conserved. This conserved quantity represents the interconversion between pure spin and pseudospin angular momentum textures to a spin-pseudospin entangled structure with quenched angular momentum, where Kane-Mele SOC tunes this balance. By these means, we achieve spin-charge interconversion of 100% efficiency via the Rashba-Edelstein effect, surpassing the previous theoretical maximum [2]. Quantum transport simulations in disordered micron-size systems demonstrate the robustness of this effect. Furthermore, our simulations also reveal a disorder resilient spin Hall effect generated by the interplay between Rashba and Kane-Mele SOC, which would otherwise be suppressed [3]. Our findings propose a platform for maximally efficient spin-charge interconversion, and establish spin-pseudospin correlations as a mechanism to tailor spintronic devices.

References

- [1] J. Medina Dueñas, et al, [arxiv:2510.21240](https://arxiv.org/abs/2510.21240)
- [2] Offidani, et al, *Phys. Rev. Lett.* **119** 196801 (2017).
- [3] Milletari, et al, *Phys. Rev. Lett.* **119** 246801 (2017).

Figures

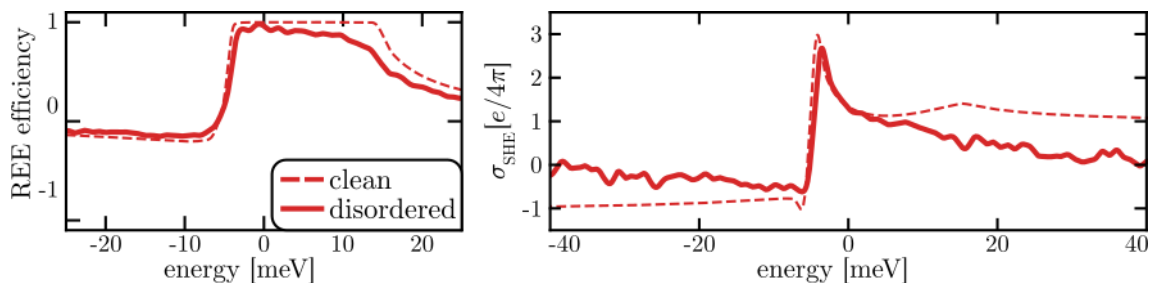


Figure 1: Disorder resilient spin-charge interconversion via the Rashba-Edelstein effect (left panel), achieving 100% efficiency, and spin Hall effect (right panel).