Optimal spin-orbit torque in graphene-based devices

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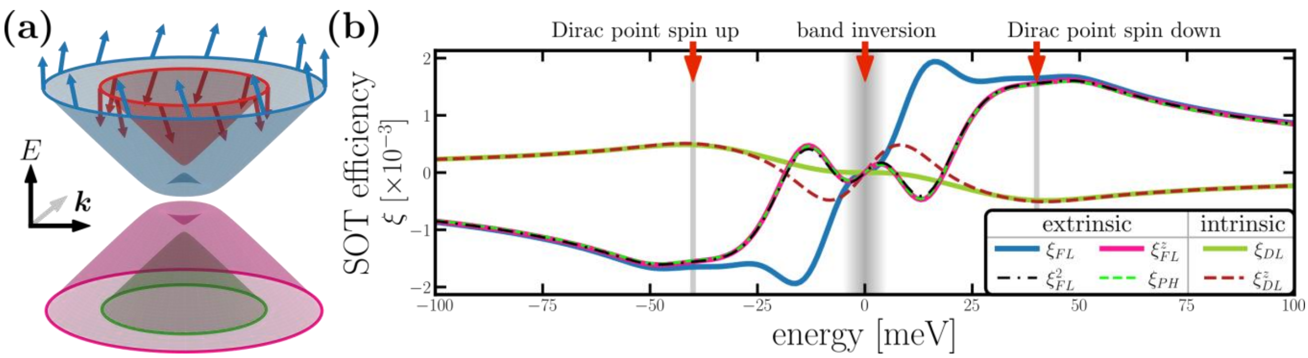
Current magnetic non-volatile memories are mainly limited by inefficient charge injection and magnet-magnet interactions. Both limitations may be overcome by replacing one magnet with a strong spin-orbit coupling (SOC) material, which acts as a current-driven spin source to control the state of the remaining magnet. Such a device is known as a spin-orbit torque (SOT) magnetic memory, and presents a major breakthrough in energy efficiency[1]. Tunable magnetic and SOC properties via proximity effects have earned graphene-based van der Waals heterostructures major attention as an efficient spintronic platform[2]. In this work we perform an extensive analysis on the SOT mechanisms in graphene with proximity-induced SOC and magnetism. We demonstrate that, in addition to the conventional field-like and damping-like torques, four non-conventional torque contributions of sizable magnitude are relevant to the magnetisation dynamics. We study the physical origin of the torques unveiling an essential role of spin-pseudospin entanglement. Our theoretical developments are supported by quantum transport simulations of large-scale devices including disorder. Our results consolidate graphene as a promising platform for magnetic memories and provides a robust path to experimentally achieving optimal spin-orbit torque.

References

[1] A. Manchon, J. Zelezny, I.M. Miron, T. Jungwirth, J. Sinova, A. Thiaville, K. Garello, and P. Gambardella, *Rev. Mod. Phys.* **92**, 035004 (2019)
[2] A. Avsar, H. Ochoa, F. Guinea, B. Ozyilmaz, B.J. van Wees, and I.J. Vera-Marun, *Rev. Mod. Phys.* **92**, 021003 (2020)



Figures

Figure 1: SOT in graphene with proximity-induced SOC and magnetisation. **(a)** Scheme for the dispersion of the system. The magnetisation shifts the Dirac points for spin up/down bands in opposite energies, with a band inversion at the charge neutrality point due to Rashba SOC. Spin texture depicted by coloured arrows. **(b)** The SOT efficiency exhibits a non-trivial behaviour with respect to the Fermi level. Close to the band inversion the system is dominated by spin-pseudospin entanglement. In this region the torque is highly tunable, and an optimal for the conventional field-like torque emerges.