Anisotropic spin dynamics and tunable spin-orbit fields in proximitized graphene

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Proximity effects in van der Waals heterostructures provide a powerful means to engineer spin-orbit coupling (SOC) in graphene, leading to anisotropic spin relaxation phenomena [1]. In this talk, I will discuss recent progress in understanding the spin dynamics of graphene interfaced with transition metal dichalcogenides (TMDCs), including 2H-TMDCs such as WS_2 and MoS_2, as well as pentagonal $PdSe_2$ [2,3]. In bilayer heterostructures of graphene and 2H-TMDCs, we observe pronounced spin-lifetime anisotropy, where out-of-plane spin lifetimes exceed in-plane values by over an order of magnitude. This behaviour stems from the imprint of strong spin-valley coupling, demonstrating how SOC in the 2H-TMDC layers profoundly influences spin relaxation in graphene [2]. By contrast, $PdSe_2$ induces a unique directional dependence in in-plane spin lifetimes due to its anisotropic crystal structure, breaking the symmetry typically observed in heterostructures with 2H-TMDCs. This anisotropy enables a 10-fold modulation of in-plane spin lifetimes and reveals the emergence of a persistent in-plane spin texture component that governs spin dynamics (Figure 1)[3]. These results, robust even at room temperature, underscore the rich spin relaxation phenomena in proximitized graphene and the potential for tailoring spin-orbit fields in two-dimensional materials.

References

[1] J. F. Sierra et al., Nature Nano. 16, 856–868 (2021)
[2] L. A. Benítez et al., Nature Phys. 14 (2018); APL Materials 7, 120701 (2019)
[3] J. F. Sierra, J. Světlík, et al. Nature Mater. https://doi.org/10.1038/s41563-024-02109-2

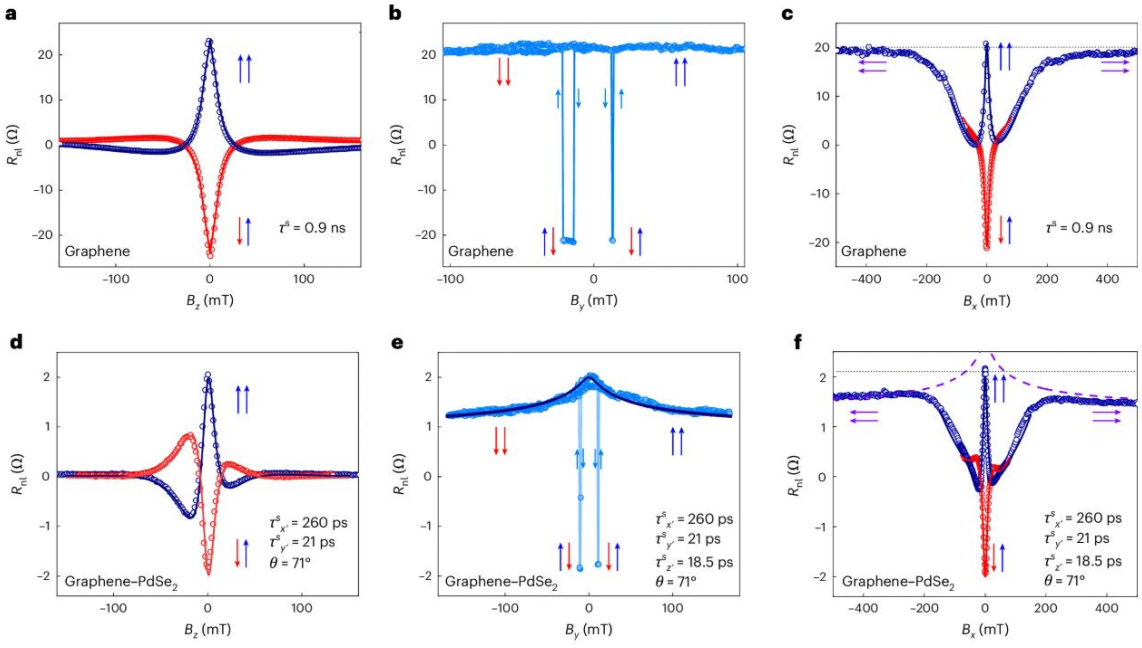

Figure 1: Spin precession lineshapes for magnetic field applied perpendicular to the substrate (z), along the ferromagnet injector detector (y) and perpendicular to them in plane (x) for a reference device (a,b,c) and in the graphene-$PdSe_2$ region (d,e,f).