Spin dynamics in graphene-based heterostructures with proximity spin-orbital effects

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Understanding spin relaxation processes in 2D van der Waals (vdW) heterostructures with strong interface-induced spin-orbit coupling is key to harness the potential of graphene for next-generation spintronic devices [1]. The spin dynamics in graphene placed on group-VI dichalcogenide monolayers has been shown to be sensitive to the competition between in-plane and out-of-plane proximity-induced pseudo-magnetic fields [2]. In experiments, this competition reflects in a giant anisotropy ratio of out-of-plane to in-plane spin lifetimes $\zeta = \tau^{\perp}/\tau^{\parallel}$. Theoretical models have been proposed to assess ζ in the weak spin-orbit coupling regime [3]. However, very little is known about the strong spin-orbit coupling (SOC) limit, where the spin splitting of electronic states is well resolved. This limit has been recently reported in vdW bilayers with atomically sharp interface, for which the spin and momentum lifetimes become comparable due to strong proximity-induced SOC [4]. In this talk, we present a theoretical study of spin dynamics in 2D vdW heterostructures with reduced C_{3v} point symmetry relevant to graphene/group-VI-dichalcogenide bilayers. We use the linear response theory to obtain the set of spin Bloch equations governing the spin dynamics at high electronic density [5]. We show how a delicate competition between Bychkov-Rashba and spin–valley interactions reflects in both the time evolution of the spin density and on ζ. Depending on the disorder-induced quasiparticle broadening, different formulae are obtained, which can be tested in ultra-clean graphene-based heterostructures to estimate the strength of the transferred proximity-induced SOC to the carbon layer [2].

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