Nonlocal Spin Dynamics in the Crossover from Diffusive to Ballistic Transport

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Improved fabrication techniques have enabled the possibility of ballistic transport and unprecedented spin manipulation in ultraclean graphene devices. Spin transport in graphene is typically probed in a nonlocal spin valve (Figure 1, left) and is analyzed using spin diffusion theory, but this theory is not necessarily applicable when charge transport becomes ballistic or when the spin diffusion length is exceptionally long. Here, we study these regimes by performing quantum transport simulations of graphene nonlocal spin valves [1] with the open-source Kwant python package [2]. We find that conventional spin diffusion theory fails to capture the crossover to the ballistic regime (Figure 1, right) as well as the limit of long spin diffusion length. We show that the latter can be described by an extension of the current theoretical framework. Finally, by covering the whole range of spin dynamics, our study opens a new perspective to predict and scrutinize spin transport in graphene and other two-dimensional material-based ultraclean devices.

References

[1] M. Vila, J. H. Garcia, A. W. Cummings, S. R. Power, C. W. Groth, X. Waintal and S. Roche, arXiv:1910.06194 (2019).
[2] C. W. Groth, M. Wimmer, A. R. Akhmerov and X. Waintal, New J. Phys., 16 (2014) 063065.

Figures

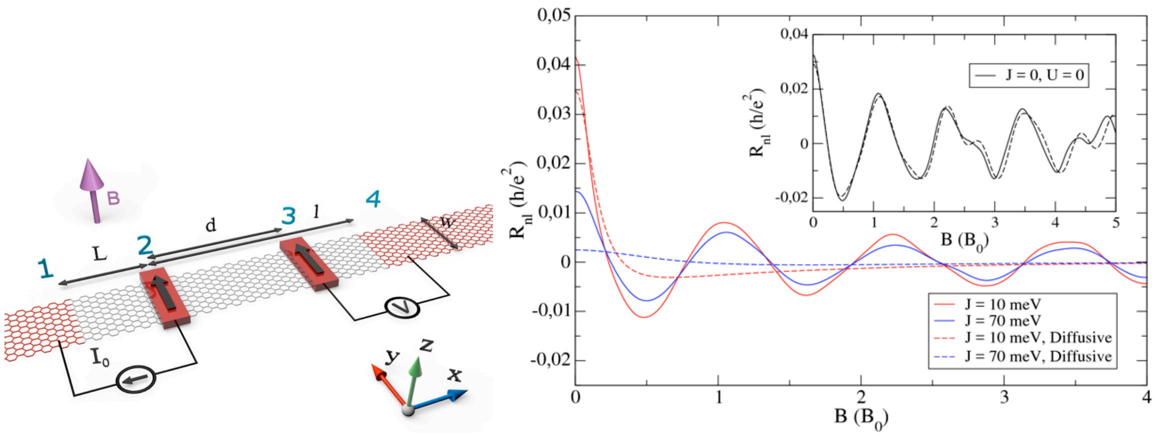

Figure 1: Left: Sketch of the lateral nonlocal spin valve. Red (black) regions denote the contacts (sample). Right: Nonlocal resistance (R_{nl}) versus magnetic field for diffusive spin transport (dashed lines), quasiballistic spin transport (solid lines) and ballistic spin transport (inset).