

Measuring anisotropic spin relaxation in graphene

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We compare different methods to measure the anisotropy of the spin-lifetime in graphene. In addition to experiments of B. Raes *et al.* [1,2] and N. Tombros *et al.* [3] we present a Hanle experiment where the electron spins precess around either a magnetic field perpendicular to the graphene plane or around an in plane field. We use exfoliated graphene on SiO₂ in a non-local geometry with Co electrodes and MgO tunnel barriers. We reproduce Raes's experiment [1], in which the magnetic field is applied at an angle β to the injector electrode (see Fig. 1). This data is consistent with isotropic spin relaxation, as in [1].

In our new experiment, we apply the magnetic field in two distinct direction, out of plane (B_{\perp}) and in plane (B_{\parallel}) as shown in Fig. 1. For this geometry we see a small difference in width and slope of the Hanle traces, displayed in Fi. 3. Although we include anisotropies of spin-lifetimes for arbitrary magnetic field directions the in plane Hanle trace cannot be well fitted. Potential reasons for this behaviour will be discussed

References

- [1] Raes, B. *et al.* Nat. Commun. **7**, 11444 (2016).
- [2] Raes, B. *et al.* Phys. Rev. B **95**, 085403 (2017).
- [3] Tombros, N. *et al.* Phys. Rev. Lett. **101**, 046601 (2008).

Figures

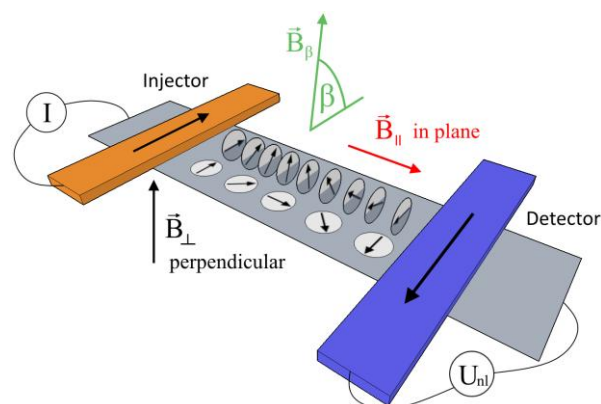


Figure 1: Sample schematic illustrating the different orientations of the magnetic fields.

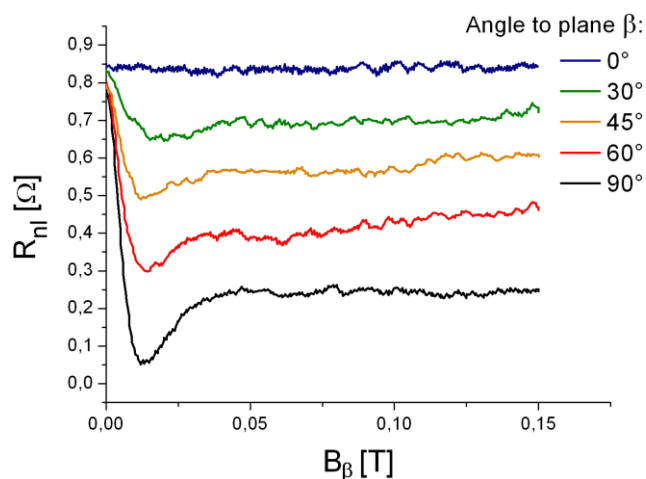


Figure 2: Spin dephasing for different magnetic field directions

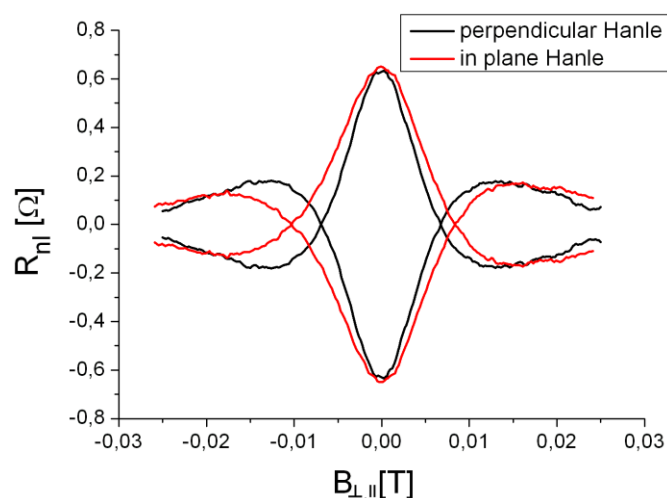


Figure 3: Comparison of Hanle curves with magnetic field perpendicular to the graphene plane (black) and in the graphene plane (red)
