Master project: The persistent spin helix in the presence of hyperfine interactions
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The field of *spintronics* pursues the active control and manipulation of the spin degree of freedom of electrons. Many interesting and useful effects have already been discovered in the past decades, such as the tunnel magnetoresistance and giant magnetoresistance (Nobel prize 2007), with applications in hard disk read heads, magnetic RAM, and magnetic sensors. The prospect of having even more accurate control over spin states would open up a whole range of futuristic possibilities such as quantum computation and quantum metrology.

One important ingredient required for many spintronic devices is a stable spin structure: the spin polarization of electrons in metals and semiconductors usually decays in a few ps, which is too fast for many applications. Recently it was shown that in quasi-two-dimensional semiconductors the strength of the two mechanisms of spin-orbit interaction (Rashba and Dresselhaus) can be tuned almost equal. In the special case where the two are exactly equal, the SU(2) symmetry of the underlying Hamiltonian is restored and one could create a helical spin structure, dubbed *persistent spin helix* (see Fig. 1a), that is robust against the most important mechanisms of spin relaxation. Indeed, experiments have been promising and showed a polarization life time of a few ns (see Fig. 1b) [1,2].

An interesting question I would like to investigate is whether the hyperfine interaction between the polarized electrons and the nuclear spins of the host semiconductor could be relevant, or maybe even useful for the spin helix. The dynamic interaction between the electronic and nuclear spins can lead to gradual polarization of the nuclear spins, which, in turn, could actually help stabilizing the helical structure of the electronic spins. Feedback effects due to hyperfine interactions have been avoided deliberately in experiments and have not been researched in theory. I think it is very interesting to investigate the coupled dynamics of a spin helix and a nuclear spin bath, since it could possibly lead to insights how to extend the life time of the persistent spin helix even further.
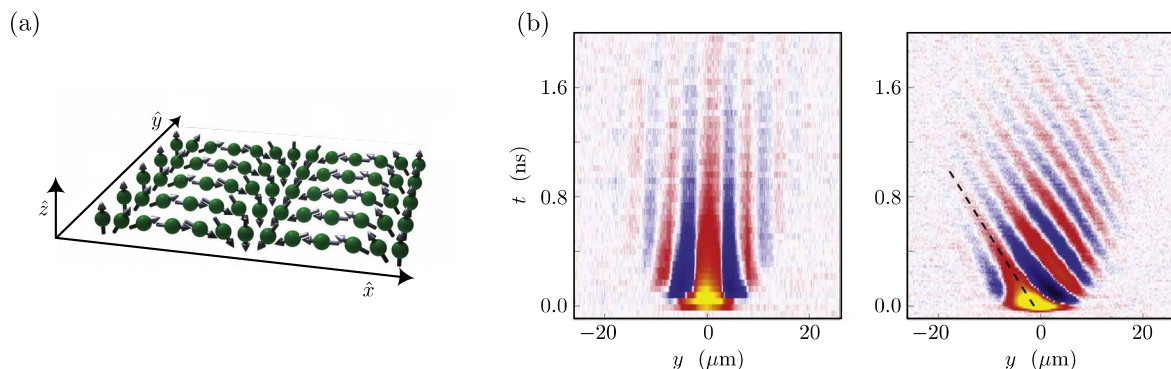

Figure 1: (a) Persistent spin helix in the *xy*-plane. Figure taken from [1]. (b) Measured slow decay of the persistent spin helix. Figure taken from [2].

[1]   J. D. Koralek et al., Nature **458**, 610 (2009).
[2]   M. P. Walser et al., Nat. Phys. **8**, 757 (2012).