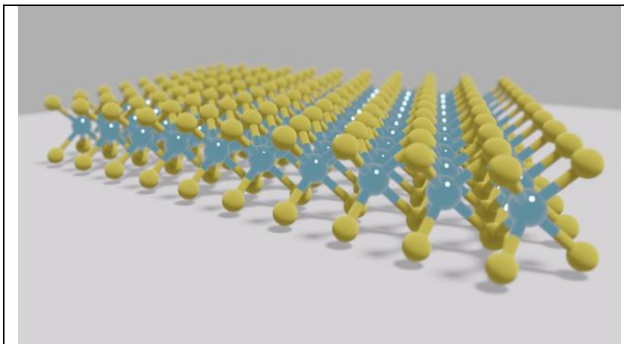
Title : Coherent manipulation of free electron spins in 2D materials		
First Name : Fabian	**Name** : Cadiz	**Laboratory** : PMC
Email : fabian.cadiz@polytechnique.edu		
Webpage : http://www.fabiancadiz.fr		
Research Area: 2D materials, semiconductor physics		
Methods: polarized photoluminescence at cryogenic temperatures		

M2 Internship subject : Currently, one of the main research topics in condensed matter physics deals with the electronic properties of atomically thin semiconductors based on transition metal dichalcogenides (TMD), such as MoS_2 and WSe_2[1,2]. Electrons in these 2D materials have promising properties due to a unique spin-texture of the K valleys of the Brillouin zone, with very long spin-lifetimes which can reach 10 µs[3], but so far only accessible through delicate pump-probe experiments based on Kerr rotation. Very recently, we have demonstrated that these resident electrons become highly spin-polarized under a steady-state, circularly-polarized optical excitation due to a dynamical polarization of the K valleys induced by exciton recombination[4]. We have shown that this spin polarization can be detected optically since it produces a large, 4-fold change of the photoluminescence intensity of negatively charged excitons when switching between circular and linear laser excitation. This finding **brings the opportunity to optically-detect the spin resonance of valley electrons** in TMD monolayers using simple, continuous wave lasers and photoluminescence detection, given for the first time a direct access to their collective coherent oscillations and g factor, the latter only accessed indirectly through phonon-assisted excitonic luminescence[5].

In this project, the intern will fabricate its own devices based on WS_2 and WSe_2 monolayers in which the resident electron density can be tuned thanks to the application of a gate voltage. The experiments will involve magneto-photoluminescence at variable temperature, in which the electron spin resonance will be driven by a radiofrequency magnetic field. This project is principally an experimental one, and would suit a student interested in fundamental semiconductor physics and 2D materials. This could lead to further work, including the possibility for a successful intern to pursue a Ph.D. financed by the ERC grant 101075855 (OneSPIN).



Representation of a monolayer of a transition metal dichalcogenide, such as WS_2 and WSe_2. In their atomically thin form, these materials are direct bandgap semiconductors where the conduction and valence bands are spin polarized. They are therefore promising building blocks in future opto(spin)tronic devices.

References

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2. Mak, K. F., Lee, C., Hone, J., Shan, J. & Heinz, T. F. Atomically thin MoS2: A new direct-gap semiconductor. *Phys. Rev. Lett.* **105**, 2–5 (2010).
3. Li, J. *et al.* Valley relaxation of resident electrons and holes in a monolayer semiconductor: Dependence on carrier density and the role of substrate-induced disorder. *Phys. Rev. Mater.* **5**, 1–11 (2021).
4. Robert, C. *et al.* Spin/valley pumping of resident electrons in WSe2 and WS2 monolayers. *Nat. Commun.* **12**, 5455 (2021).
5. Robert, C. *et al.* Measurement of Conduction and Valence Bands g -Factors in a Transition Metal Dichalcogenide Monolayer. *Phys. Rev. Lett.* **126**, 67403 (2021).