POLYTECHNIQUE MONTRÉAL

LE GÉNIE EN PREMIÈRE CLASSE

SÉMINAIRE DU DÉPARTEMENT DE GÉNIE PHYSIQUE

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Amphithéâtre du Pavillon J.-A. Bombardier, salle 1035

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Electrons, holes, and excitons in monolayer semiconductors:
Insights from optical spectroscopy in (really) high magnetic fields

Much of the current interest in the new family of atomically-thin 'transition metal dichalcogenide' (TMD) semiconductors such as MoS2 and WSe2 derives from the physics of coupled spin & valley degrees of freedom and the potential for new spin/valley-based devices. This talk will introduce these materials, and discuss recent optical studies that probe the physics of electrons, holes, and excitons in monolayer TMD semiconductors, as well as the crucial role played by the surrounding dielectric environment.

Our first studies focused on revealing fundamental properties relevant for optoelectronics, such as exciton mass, size, binding energy, and dielectric screening. To date, many of these parameters are still assumed from density functional theory. Historically, magneto-optical spectroscopy has played an essential role in determining these properties in semiconductors; however, for TMD monolayers the relevant field scale is substantial –of order 100 tesla!– due to heavy carrier masses and huge exciton binding energies. Fortunately, modern pulsed magnets can achieve this scale. Using exfoliated monolayers affixed to single-mode optical fibers, we performed low-temperature magneto-absorption spectroscopy up to ~90T of all members of the monolayer TMD family. By following the diamagnetic shifts of the exciton's *1s* ground state *and* its excited *2s, 3s, ... ns* Rydberg states, we determined exciton masses, radii, binding energies, dielectric properties, and free-particle bandgaps [1, 2]. These data provide essential ingredients for the rational design of optoelectronic van der Waals structures.

In separate studies we developed an entirely passive, noise-based approach for exploring the intrinsic spin & valley *dynamics* of electrons and holes in monolayer TMD semiconductors [3]. Under conditions of strict thermal equilibrium, we use optical techniques to "listen" to the thermodynamic fluctuations of the valley polarization in a Fermi sea of resident carriers, due to their spontaneous scattering between the *K* and *K'* valleys of the Brillouin zone. The spectra of this 'valley noise' reveals encouragingly long valley relaxation timescales (up to microseconds), and provides a viable route toward quantitative measurements of intrinsic dynamics, free from any external perturbation, pumping, or excitation.

[1] M. Goryca *et al.*, *Nature Comm.* **10**, 4172 (2019)
[2] A. V. Stier *et al.*, *Phys. Rev. Lett.* **120**, 057405 (2018)
[3] M. Goryca *et al.*, *Science Advances* **5**, eaau4899 (2019)

Scott A. Crooker *received a B.A. in physics from Cornell University in 1992 and a Ph.D. in physics from UC Santa Barbara in 1997. Following a postdoc at the National High Magnetic Field Laboratory at Los Alamos National Lab (NHMFL-LANL), he has continued as a permanent member of the NHMFL scientific staff. His research interests focus on the development of sensitive magneto-optical spectroscopies to probe both the static and dynamic behavior of spins and magnetism in novel semiconductor materials. He is a LANL Fellow, and a Fellow of the APS, AAAS, and OSA.*

Vous êtes tous les bienvenus.

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