**EMPLOYMENT PORTAL SECTION**

**CONTENT** PhD Student – *fixed-term contract*

LABORATOIRE PMC

## Title of post

M/W PhD position in physics; Spin-resolved cathodoluminescence in van der Waals heterostructures

## General information

***Reference*** **: Poste2018001 (cf AM)**
***Workplace*** **: Laboratoire de Physique de la Matière Condensée –LPMC- Ecole polytechnique – Route de Saclay – 91128 Palaiseau cedex**
***Date of publication :***
***Scientific Responsible name : Fabian Cadiz***
***Type of contract : doctoral contract***
***Contract period : 3 years***
***Expected start date of thesis : 01/03/2019***
***Proportion of work (e.g full-time=100%) : 100 %***
***Remuneration ::***

## Description of the thesis subject

Atomically thin transition metal dichalcogenides (TMDCs), such as $MoS_2$, $MoSe_2$, $WS_2$ and $WSe_2$ are promising 2D semiconductors for future nano-electronics and optoelectronics. Due to an enhanced Coulomb interaction when electrons and holes are confined in two dimensions, bound electron-hole pairs, or excitons, dominate the optical properties of these materials even at room temperature [1]. The unusually large exciton binding energy in these materials provides a model system for investigating 2D excitons. In addition, their unique band structure is characterized by two kinds of non-equivalent, spin-polarized valleys at the hexagonal corners of the Brillouin zone, a promising feature for valleytronics. This spin-valley coupling provides chiral optical selection rules that make possible to optically inject carriers in a given valley by using circularly polarized light. In addition, different 2D layers can be now stacked together to form new materials in which the different quantum states found in the individual layers can interact and form novel excitations that serve as alternative carriers of the transport of valley information. These van der Waals heterostructures are thus among the most promising candidates for future valleytronic applications [2].

The aim of this PhD project is to fabricate van der Waals heterostructures by mechanical exfoliation of bulk crystals and to investigate the spin-valley coupling and dynamics by different luminescence techniques. The PhD candidate will contribute to the conception of a novel spin-resolved cathodo-luminescence experiment in which a spin-polarized electron source will be used to inject electrons into 2D materials and the resulting polarized-luminescence will serve to probe the valley-contrasting properties of these materials.

These measurements will be complemented by an all-optical micro-photoluminescence experiment recently developed at PMC. Here a tightly focused, circularly-polarized laser beam is used to locally inject excitons in a given valley and their steady-state spatial distribution will be mapped through the imaging of the resulting photoluminescence intensity [4]. This setup allows for a simultaneous measurement of the degree of circular polarization of the luminescence, and therefore to also track the spatial evolution of the valley-index of the photo-injected carriers. The effect of exciton density, tunable via the laser power, as well as the sample temperature on the spin-valley dynamics will be studied.

This PhD is principally an experimental one, and would suit a student interested in fundamental semiconductor physics and 2D materials.


[1] G. Wang et al., Excitons in atomically thin transition metal dichalcogenides, Rev. Mod. Phys. 90, 021001 (2018)
[2] K.S. Novoselov et al., 2D materials and van der Waals heterostructures, Science 353, aac9439 (2016)
[3] S. Zheng et al., Giant Enhancement of Cathodoluminescence of Monolayer Transition Metal Dichalcogenides Semiconductors, Nano Lett. 17, 6475 (2017)
[4] F. Cadiz et al., Exciton diffusion in $WSe_2$ monolayers embedded in a van der Waals heterostructure, Appl. Phys. Lett. 112, 152106 (2018)


## Work context

**PMC is one of 22 laboratories located at the Ecole polytechnique research centre working on the frontier of knowledge on the major interdisciplinary scientific, technological and societal issues.**
**Within the Teaching and Research Department of Ecole polytechnique, PMC (Laboratoire de Physique de la Matière Condensée) is a mixed research unit (Ecole polytechnique/CNRS) whose work is organized around two fundamental topics that are the nanosciences and the physics of Irregularity.**
**We try to understand the solid, liquid or intermediate states (gel, pastes, foams…)of matter (structure, properties, phenomena of sets related to the interactions between the particles that compose it), the condensed matter physics is a science that is upstream of innumerable technological advances.**

For further information see the team's website : https://pmc.polytechnique.fr/spip.php?article549 and the websites of the two PhD supervisors Fabian Cadiz and Fausto Sirotti.

## Constraints and risks

The Ph.D. will be carried out under the auspices of the Interfaces doctoral school. Travel in France and internationally for periods up to one week should be envisaged in the context of scientific conferences.

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| Supplementary information | This PhD would suit a student with a background in solids state physics at the masters level. A specialization in semiconductors would be an advantage but is not a pre-requisite. The proposed project would suit someone who enjoys experimental work, but some knowledge of numerical modelling techniques would be an advantage.<br><br>We are looking for a PhD candidate who will be fully involved with the project, with a thirst for knowledge, a certain independence of thought, and strong motivation to develop skills in semiconductor physics and laser based experimental techniques. In addition, the candidate must be able to work in a team.<br><br>Applications must include a detailed resume; at least two references (people who may be contracted); a cover letter of one page; a one-page résumé of the dissertation for the master; and grades obtained for the master 1 or 2 degree.<br><br>**The closing date for sending applications is 01/04/2019** |