PhD topic proposal (2023)

Laboratory: Centre de Nanosciences et de Nanotechnologies (UMR 9001, France)+ Micronova/Aalto University, Tietotie 3, 02150, Espoo, Finland: Pr. Zhipei Sun's group C2N's address: 10 Boulevard Thomas Gobert – 91120 Palaiseau, France	Centre de Nanosciences et de Nanotechnologies
Contact at UPSaclay: Éric CASSAN eric.cassan@universite-paris-saclay.fr https://minaphot.c2n.universite-paris-saclay.fr	

"On-chip ultra-miniaturized spectrometers with 2D materials"

Research project description:

Miniaturized computational spectrometers, which can obtain incident spectra using a combination of device spectral responses and reconstruction algorithms, are essential for on-chip and implantable applications. Highly sensitive spectral measurement using a single detector allows the footprints of such spectrometers to be scaled down while achieving spectral resolution approaching that of benchtop systems. Very recently, a high-performance computational spectrometer based on a s**ingle van der Waals (vdW) junction with an electrically tunable transport-mediated spectral response** was reported by our research groups **[1]**. High peak wavelength accuracy (~0.36 nanometers), high spectral resolution (~3 nanometers), broad operation bandwidth (from ~405 to 845 nanometers), and proof-of-concept spectral imaging were demonstrated. The following approach provides a route toward spectrometer ultra-miniaturization and offers unprecedented performance in accuracy, resolution, and operation bandwidth for single-detector computational spectrometers. Electrical tuning of the interfacial band alignment of a vdW junction enabled controllable and distinctive interlayer transport. Such electrically controllable interlayer transport allowed for a tunable spectral response with high sensitivity and variability over a wide spectral range, demonstrating that a single vdW junction spectrometer could achieve substantially higher performance than previously reported spectrometers (see **Fig. 1**).

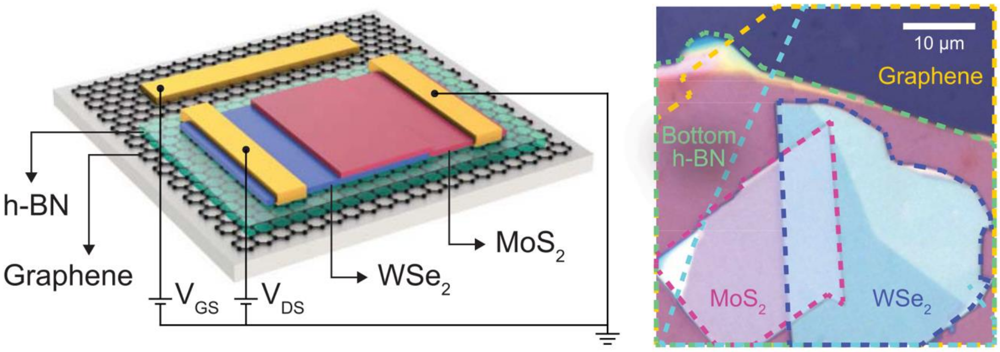

Fig.1: Schematic of the MoS_2/WSe_2 heterojunction spectrometer and its optical images on the h-BN and graphene layers before depositing electrodes and stacking the top h-BN passivation layer realized at the Aalto university.

The key driver of the proposed PhD project is to develop an innovative action towards the realization of integrated spectrometer structures based on this principle. Changing the paradigm from vertical illumination to edge illumination by the mean of photonic waveguides connected in circuits, the functions will be enriched by **all the possibilities offered by photonic integration** that will be considered and explored. Integrated with optical waveguides will be considered by relying on different photonic platforms, including silicon nitride and silicon photonics **[2]**.

The possibilities to be explored are very rich in terms of:

- Materials, by considering different types of 2D materials for the realization of vdW junctions targeting different spectral windows,
- Photonic waveguides: strip, slot, sub-wavelength waveguides,
- Photonic platforms: silicon nitride, silicon.

and will lead to breakthroughs.

The PhD thesis project is part of an international PhD cotutelle application and draws on the complementary expertise of two research groups:
- Aalto University (Helsinki / Finland): expert group in materials science,
- Paris-Saclay university (C2N - Palaiseau / France): an expert group in optics/photonics and supported by a micro-fabrication clean room **(Fig. 2)**.

Half of the thesis will be carried out on each site according to a schedule to be defined later in the service of the scientific project. The person recruited will therefore evolve in an international context and will be trained in contact with two French and Finnish teams which know each other very well [3,4] as well as through the cultures and methods of doctoral trainings at the two universities. A final single PhD defense and a single manuscript will lead the PhD candidate to get the PhD degrees of the two universities.

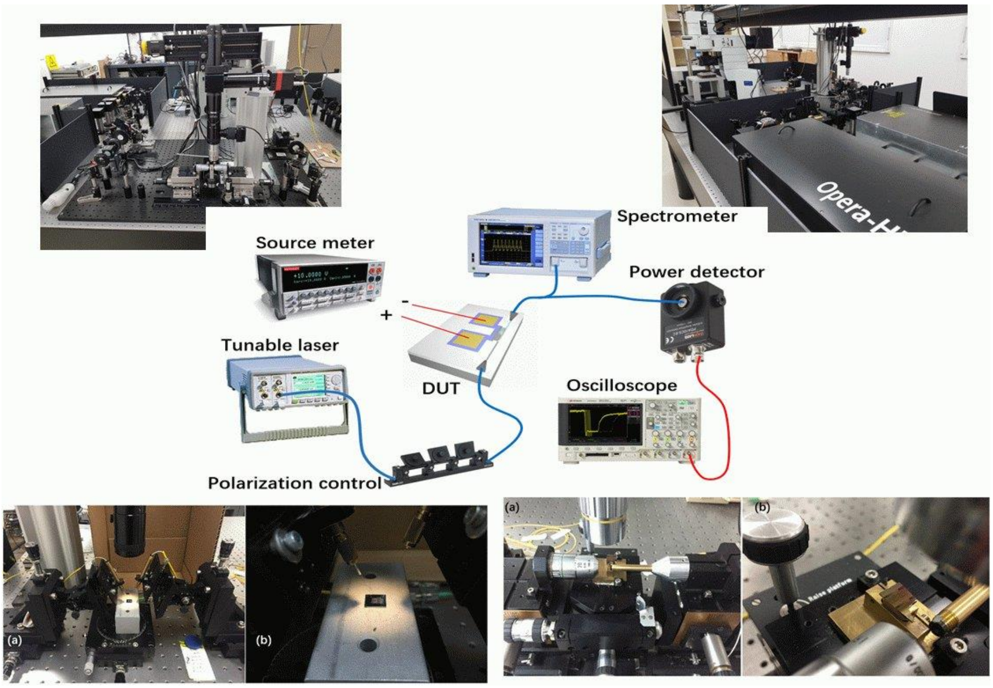

Fig.2: Some illustrations of the experimental facilities available at the C2N laboratory host team / UPSaclay-CNRS.

We expect from you:

- Enthusiasm and strong involvement in your project, a growing autonomy, and the ability to address your topic as a project with milestones and deliverables
- Taste for **Material Science** and **Optics&Photonics**, including experiments and simulation
- Ability to communicate and work in a group, an open-minded attitude and an ability to conduct a project by addressing questions to relevant people around you

For any questions, ask for references, and to apply:

eric.cassan@universite-paris-saclay.fr

References:

[1] **"Miniaturized spectrometers with a tunable van der Waals junction"**
Yoon et al. (including Zhipei Sun as the last author), **Science**, 378, 296–299 (2022) - https://www.science.org/doi/10.1126/science.add8544

[2] **"Roadmap on silicon photonics"**
David Thomson, Aaron Zilkie, John E Bowers, Tin Komljenovic, Graham T Reed, Laurent Vivien, Delphine Marris-Morini, Eric Cassan, Léopold Virot, Jean-Marc Fédéli, et al.
Journal of Optics, Volume 18 (7), 073003, https://iopscience.iop.org/article/10.1088/2040-8978/18/7/073003

[3] **"Ultra-high on-chip optical gain in erbium-based hybrid slot waveguides"**
J. Rönn, W. Zhang, A. Autere, X. Le Roux, L. Pakarinen, C. Alonso-Ramos, A. Säynätjoki, H. Lipsanen, L. Vivien, E. Cassan, Z. Sun, **Nature Communications**, 10:432 (2019), https://doi.org/10.1038/s41467-019-08369-w

[4] **"Erbium-doped hybrid waveguide amplifiers with net optical gain on a fully industrial 300 mm silicon nitride photonic platform"**
John Rönn, J. Zhang, W. Zhang, Zhengrui Tu, Antti Matikainen, X. Leroux, E. Durán-Valdeiglesias, N. Vulliet, F. Boeuf, C. Alonso-Ramos, H. Lipsanen, L. Vivien, Z. Sun, E. Cassan, **Optics Express**, 28 (19), pp. 27919-27926 (2020)