

Master Internship/Master thesis proposal (2023)

Laboratory: **Centre de Nanosciences et de Nanotechnologies (UMR 9001, France)**

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“Early stages on photonic integration towards ultra-miniaturized spectrometers with 2D materials”

Master internship / Master thesis 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 **single van der Waals (vdW) junction with an electrically tunable transport-mediated spectral response** was reported [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 provided 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**).

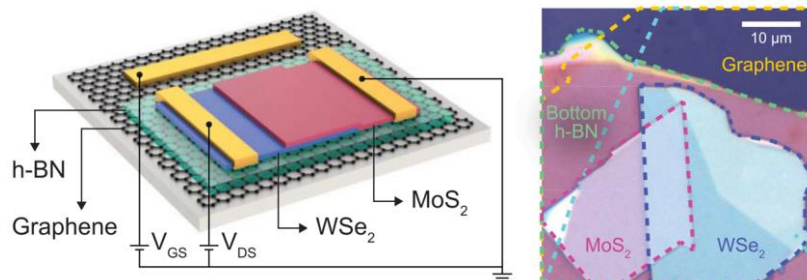


Fig.1: Schematic of the MoS₂/WS₂ heterojunction spectrometer and its optical images on the h-BN and graphene layers before depositing electrodes and stacking the top h-BN passivation layer realized at the Aalto university.

The key driver of the proposed Master project is to initiate 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]. This Master internship / Master thesis proposal can be seen as a preliminary step before a **PhD thesis project that will be part of an international PhD cotutelle application** and that can draw 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.

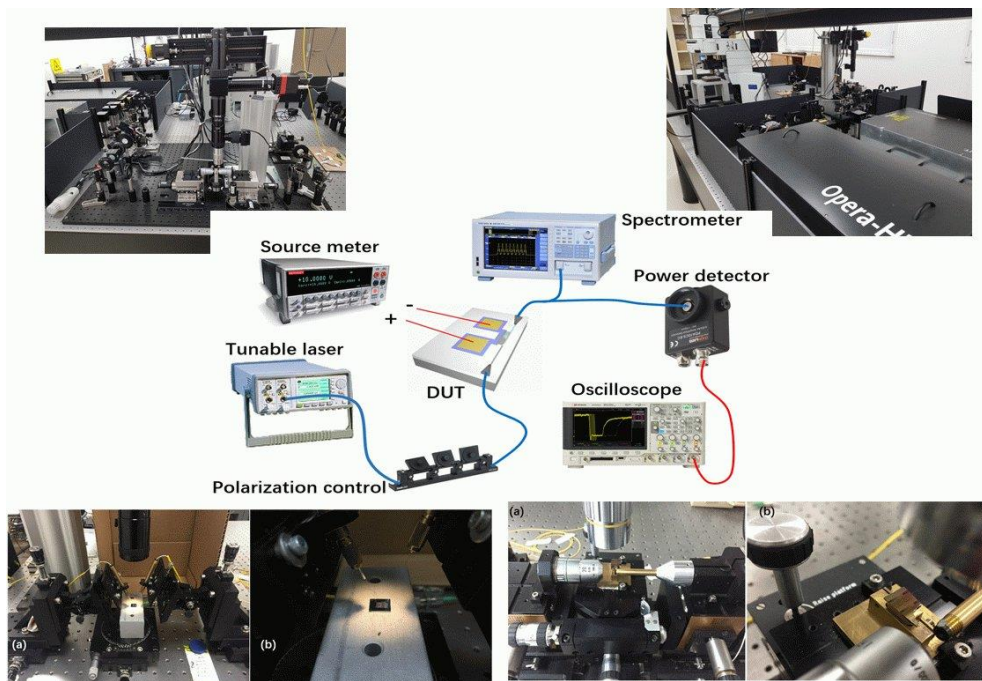


Fig.2: Some illustrations of the experimental facilities available at the C2N laboratory host team / UPSaclay-CNRS.

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 : **our collaborator at Aalto university/Primary investigator**), **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 Viro, Jean-Marc Fédéli, et al.
JOURNAL OF OPTICS, Volume 18 (7), 073003, 2016 <https://iopscience.iop.org/article/10.1088/2040-8978/18/7/073003>