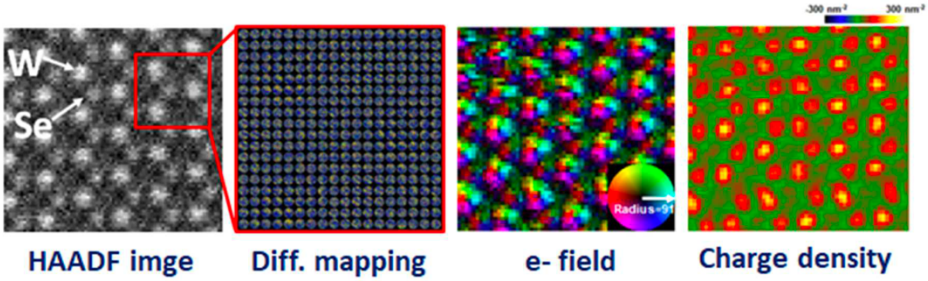
# NÉEL INSTITUTE Grenoble

## Topic for Master 2 internship – Academic year 2024-2025

### Measuring electric fields at nm length scales using 4D scanning transmission electron microscopy

**General Scope :** Long range electric and magnetic fields are present all around us in devices, where electric fields on atomic length scales are present in all matter. However, it remains challenging to measure the strength of these fields accurately and with high spatial resolution. Several Transmission Electron Microscopy (TEM) based techniques exist, sensitive to internal fields. TEM is of particular interest in this respect, since (i) the electron traverses the sample, and can therefore probe all fields it traverses, and (ii) due to the very high spatial resolution that can be obtained in TEM.

**Research topic and available facilities**: The aim of this internship is to contribute to the data treatment of so-called four-dimensional scanning transmission electron microscopy (4D STEM) results. In these experiments, a focused electron probe is raster scanned over the sample, and a diffraction pattern is acquired at each probe position. The presence of an (electric) field in the sample results in a deflection of the transmitted beam as well as a phase change. Different methods exist to calculate the phase and amplitude image from such a four-dimensional data-set, and this field is evolving very rapidly. However, this kind of data treatment is not yet available for day to day use on our TEM. The student will integrate an existing project on electron ptychography, either making the ptychographic reconstruction more available to users, or comparing different reconstruction algorithms, on both experimental and simulated diffraction maps, building on our experience in this field. The student will integrate a multi-institute, multi-disciplinary research group, including researchers of both CEA Grenoble and CNRS Institut Neel. The student will assist to the 4D STEM experiments and data acquisition on a state-of-the-art corrected TEM present at Institut Neel, equipped with a new very fast camera. The student will compare approaches using already developed scripts and programming in Python and adapt python scripts to the task. An example of such a 4D data set is shown in the figure, accompanied by the calculated electric field and charge density.




*HAADF image of $WSe_2$ monolayer (2D material), local electric field and charge density maps calculated from deflection of transmitted beam.*

**Possible collaboration and networking :** The internship will be in collaboration with researchers from IRIG.

**Possible extension as a PhD :** We are open to support applications for a PhD grant.

**Required skills :** Interest in solid-state physics, transmission electron microscopy, interest in programming and data treatment.

**Starting date** : jan/feb 2025

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