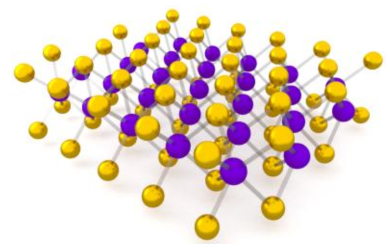
Valley Dynamics in novel two-dimensional materials



Structure of a type MX_2 TMD monolayer.

Atomically thin transition metal dichalcogenides (TMDs) are new and exciting materials which share many interesting features with graphene, yet – since they belong to semiconductors family – they are much better suited for optoelectronic applications such as light emitters and photodetectors. Moreover, due to peculiarities of their structure, the polarization of light absorbed (or emitted) by those materials is related to the motion of electrons inside them in a very specific way. This unique property opens a new field of optoelectronics called "*valleytronics*" in analogy to *spintronics*. In *spin*tronics the storage and manipulation of information is based on electron's *spin*, while TMDs offer the additional possibility to encode information in an electron's *valley* (*i.e.*in a way the electron moves inside the TMD crystal, or – in other words – in which *valley* in so-called momentum space the electron resides).

The key to any application in memory or information processing devices is the knowledge of the processes responsible for information loss. Recent conventional studies have suggested that such information loss can be relatively slow in a TMD-based system. However, a significant drawback in all such conventional studies is that they are necessarily perturbative – by design they require driving the system out of equilibrium (*e.g.* with a strong laser pulse), which can cause different problems with the experiment itself and with the interpretation of its results. The completely alternative approach that was recently presented by the Principal Investigator of this project is based on the idea of just passively "listening" to the random fluctuations (*i.e.* noise) of electrons in the TMD structure. Those studies, avoiding all problems caused by the perturbative nature of conventional experiments, have unambiguously proven that the loss of valley-encoded information (*i.e.* "*valley relaxation*") in a TMD structure is very slow indeed, at least when the system is kept at very low (cryogenic) temperature.

Despite all this progress, however, the details of the mechanisms responsible for the information loss remain little explored. Detailed knowledge on those mechanisms is crucial for any valleytronic applications, especially for devices designed to work at elevated (non-cryogenic) temperatures. **The aim of this project** is to combine state-of-the-art experimental methods to perform a comprehensive study of valley relaxation in a variety of novel TMD systems. On one hand, as a main tool to measure the valley relaxation the researchers will use the valley noise spectroscopy – a novel technique recently pioneered by the Principal Investigator. On the other hand, the focus will be put on TMD structures prepared with unique methods, including Molecular Beam Epitaxy (MBE). The use of MBE technique to fabricate atomically thin TMD layers of high quality was recently pioneered by researchers from the Host Institution (the University of Warsaw), which is currently the *only* place in the world where such capability is available. Combination of the experience of the Principal Investigator related to unique measurement techniques, together with novel fabrication methods developed at Host Institution, is anticipated to give unprecedented insight into the valley relaxation mechanisms in monolayer TMD structures. This, in turn, will advance the quest for robust and efficient valleytronic memories and information processing devices.