DESCRIPTION FOR THE GENERAL PUBLIC

The main subject of the project concerns the studying of spin and pseudospin of energetically controlled dark and bright excitons in novel two dimensional (2D) materials, tailored semiconducting transition metal dichalcogenides (TMDCs), namely $Mo_{1-x}W_xSe_2$ monolayers. Monolayers of TMDCs have attracted considerable attention following the discovery of the indirect-to-direct band-gap transition and the coupling of the spin and valley degrees of freedom when thinned down to monolayer. In TMDCs excitons have very high binding energies of a few hundreds of meV, which leads to their stability at room temperature, very attractive for applications in optoelectronics. The important characteristic of TMDC is the strong spin-orbit interaction, leading to the splitting between the dark and bright exciton subbands of the so-called A-exciton defined by the spin-orbit splitting of the conduction band, Δ_{so}. Excitons composed of the electron and hole with the same spin are bright and with opposite spins are dark. A consistent picture about the interaction between optically bright and dark excitons at the +K and -K valleys is missing. For that purpose, a system is highly desirable, in which the exciton spin states can be tuned in a controlled manner in order to energetically order and even mix the exciton states. $Mo_{1-x}W_xSe_2$ alloys are very promising for such a study, since as demonstrated by theory, for both end members of the series $MoSe_2$ and WSe_2 the $|\Delta_{so}|\approx$20-40 meV is expected but is predicted to be negative in WSe_2 leading to the lowest energy dark exciton subband in contrast to $MoSe_2$ where, Δ_{so} is positive and the lowest exciton subband is bright. In such a tunable system, novel insights into the spin and valley pseudospin properties of the excitons as well as the spin-orbit coupling in the valence and, particularly, conduction band can be expected, which are of emerging interest for the spin- and valleytronics fundamental research and applications. The tuning of the exciton states may reveal novel details about the carrier-carrier interactions of the excitons, namely exchange interactions, and the interaction of the excitons with the surrounding bath including nuclei and phonons. The electron-nuclear spin coupling combined with valley addressability as well as exciton-phonon scattering has not been characterized in this materials yet.

The monolayers of $Mo_{1-x}W_xSe_2$ alloys will be obtained from high quality bulk crystals by mechanical exfoliation. The experimental part of the project will involve advanced optical spectroscopy:

1. Comparative studies of polarization resolved, temperature dependent (7-300K) photoluminescence (PL) and reflectance contrast (RC) spectra of the $Mo_{1-x}W_xSe_2$ monolayers under different experimental conditions (in vacuum, He, ambient and N_2 at T = 300K) under resonant and non-resonant excitations.
2. Polarization resolved Raman spectra of the $Mo_{1-x}W_xSe_2$ monolayers with of different laser excitation (532 nm, 633 nm), at T = 295 K, in ambient, in high vacuum and under N_2, He environment.
3. Time-resolved PL to study spin and valley physics.
4. Combination of the PL studies with ODMR and ODNMR techniques and strain application.