Theoretical study of the magnetoresistance phenomena in 2D structures with strong spin-orbit interaction

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Spin-orbit interaction can be seen as an effective internal magnetic field which acts on the electron spin instead of its charge. Since this intrinsic field couples orbital and spin degree of freedom, it opens a unique possibility of pure electrical control the spin-degree of freedom. Recent spin electronics focus on the efficient spin-to-charge conversion, that is, for instance, the conversion of electric current into the spin current or spin accumulation. Thus, spin-orbit interaction provides various possibilities of such interconversion. As an example, one can indicate spin Hall effect or current-induced spin polarization (also known as Edelstein effect). These phenomena have various microscopic origins that might be intrinsic (governed by special symmetry of the system) and extrinsic that are related to some spin-dependent scattering processes.
Moreover, very recently it has been observed that the resistance of some nonmagnetic systems possessing strong spin-orbit interaction reveals under the external magnetic field quite interesting behavior. Namely, it depends linearly on both electric and magnetic field simultaneously. That is why it is called bilinear magnetoelectric resistance (BMER).

The aim of this project is providing a theoretical description of BMER, and other unidirectional phenomena observed experimentally very recently. Moreover, the project objective is also an indication of efficient ways of measurement the spin-to-charge interconversion phenomena.

Understanding the physical origins responsible for BMER and other unidirectional effects allow for their application in new electronics devices. In principle, one can think about the new kind of the read-write protocols in the hard drives and logic devices, where the "0" and "1" states related with high and low resistance state of the electronic element can be provided by the two opposite current flow directions.

Within the project, it is also assumed to study the electronic and spin transport through so-called van-der-Waals heterostructures. These hybrid systems are designed by stacking on top of each other different two-dimensional crystals such as graphene, hexagonal boron nitride, silicene (two-dimensional crystal of silicone), a single layer of transition metal dichalcogenides, etc. Thus, such structures are unique, artificial materials with dedicated electronic and magnetic properties for a specific spintronic device. In this project under special attention will be such van-der-Waals heterostructures for which magnetic and spin proximity effects allow to create some new spin valves, spin filters or spin transistors possessing strong magnetoresistance response (e.g., strong giant or tunneling magnetoresistance, strong unidirectional magnetoresistance).