NEW PLATFORM FOR STUDY WAVE PHENOMENON – RECONFIGURABLE TOPOLOGICAL PROPERTIES AND FURSTURED GROUND STATES IN MAGNONICS

Magnetic moments can rotate in precessional motion around the direction of the equilibrium orientation, if they are pushed out from the equilibrium position, quite like a toy spinning top. In a ferromagnetic material due to the interaction between magnetic moments located on the atomic sites, the disturbance of the magnetic moment on one site can coherently propagate in the form of waves through the structure. These waves are called ***SPIN WAVES***, they can transmit spin, energy, and thus information, like waves of the other nature, e.g., electronic or electromagnetic. Typical frequencies of spin waves lay in the range from few GHz to hundreds of GHz with their respective wavelengths in the range from hundreds down to tens of nanometers. This makes spin waves suitable for design of miniaturized devices for processing information operating at high microwave frequencies. The research field focused on spin waves and developing spin wave based technology is called ***MAGNONICS***. The main advantages of magnonics over electronics and photonics are: simplicity of inducing nonlinear effects required by many signal processing applications, anisotropy and reconfigurable property related to different magnetization textures, inherent to magnetic materials nonreciprocal effects, and low energy consumption. It is expected, that magnonic devices can fill the gap in information processing devices between strongly miniaturized microelectronics and ultrafast photonics through fabrication energetically efficient, miniaturized and fast logic units.

The dispersion relation of waves gives the fundamental connection between frequency and the wavelength, which allows to derive many properties useful and necessary for description of waves dynamics, like phase and group velocity. Especially interesting are materials which are periodic on the scale comparable with the wave wavelength – **MAGNONIC CRYSTALS**, counterpart of semiconductors for electrons. If a medium has periodicity, the dispersion relation of wave is formed by frequency bands and bandgaps which determines the frequency ranges where propagation of waves is allowed and prohibited, respectively. Especially interesting, from basic physics, but also application point of view, are bands which allow propagation of waves only in one direction. In this case back scattering is prohibited and a high transmission is expected even through the curved paths. Such property possess bands which are **topologically protected**. Nobel Prize in physics in 2016 was just for theoretical discovery of topological phase transitions and topological phases of matter. Topologically protected waves are hot topic in many brunches of physics. However, in magnonics only a few theoretical papers predicted unidirectional edge-localized spin waves has been published so far.

The main objective of the project is to define the magnonic crystal based on multilayered films with an regular array of holes, possessing multiple magnetization states suitable for formation of the confined and propagating spin waves with nontrivial topological properties. We hope to offer the crystal which becomes an universal platform for study new effects in magnonics. To prove that, we will demonstrate three breakthrough ideas providing new effects and potential applications. *The first idea is to show the structure for efficient transduction of global microwave signal to propagating spin waves in sub-micron scale. The second idea is to form magnonic crystal with topologically protected spin wave bands induced on demand by magnetization texture near the holes. The third one is to propose a new type of artificial spin ice structure possessing frustrated ground state and allowing to guiding spin waves.*

We will investigate spin waves in multilayers with perpendicular magnetic anisotropy induced at interfaces between the layers in symmetric and asymmetric Co(CoFeB)/Pt(Au,NiO) multilayers, which under some conditions allow also to control the chirality of the magnetization texture. The anisotropy keeps the magnetization stable perpendicular to the film plane even without the bias magnetic field. The focused ion beam (FIB) used to pattern will be used also to decrease the anisotropy near the holes where the demagnetizing field will align magnetization in plane offering required properties for project realization.

The research in the project will extend the knowledge about spin wave dynamics in ferromagnetic materials with non-trivial magnetization textures. Magnetic configuration near the patterned holes can be programmable by different re-magnetization processes, which we will develop in the project. The proposed studies will enhance **possibility for applications of the magnonic devices to processing, computing and routing of the high-frequency signals** in miniaturized devices.