Magnetic moments can rotate in precessional motion around the direction of the static magnetic field if they are pushed out from the equilibrium position (e.g. by application of the radiofrequency field, or by thermal excitation). In a magnetic medium, due to the interaction between magnetic moments, the waves of coherently precessing magnetic moments can propagate. These waves, (called *spin waves*), can transmit energy and information, similarly like waves of a different nature (e.g. electromagnetic waves or elastic waves). The systems, which use the spin waves for processing and transmitting information can fill the gap between electronics and photonics. Typical frequencies of spin waves (in the range from a fraction of GHz to hundreds of GHz) and their wavelengths (in the range from tens to hundreds of nanometers) make possible the design of miniaturized devices (called *magnonic devices*) operating on high-frequency signals. The main advantages of *magnonics* over the other technologies are (i) simplicity of inducing nonlinear effects (useful in many tasks related to signal processing), (ii) anisotropy in the propagation of waves and (iii) nonreciprocal effects for the propagation of waves making a possible design of circulators and isolators. The dispersion relation describes the dynamical properties of the system operating on coherent signals (i.e. the signals in the form of waves). It gives the fundamental relation between frequency and the wavelength. Dispersion relation allows deriving a lot of features and parameters useful for the description of wave dynamics. We can itemize the following: location and width of the frequency gaps (determining the frequency of the wave where propagation is not allowed through the system), group velocity and phase velocity.

One of the basic methods suitable for spin wave dispersion relation modification is introduction of a periodical modulation of magnetic properties. Created in such a way periodic structure is typically referred to as magnonic crystal and is characterized by the existence of frequency bandgaps with ranges of forbidden frequencies. A unique property of spin waves is the fact that they propagate in magnetic media. Features of this environment, suitable for SWs propagation, can be easily molded, e.g., by the external factors like the magnetic field, but also by the internal magnetization texture. It means, that this periodical modulation can be also introduced by the magnetization texture without any change of system's structure.

The concept of periodic modulation was just recently extended from space into time, leading to the idea of a time crystal by Wilczek in 2012. The combination of space and time symmetry breakings defines a so-called Space-Time Crystal that exhibits periodicity in space and time. **In the frame of this Project we unite the fundamental space-time crystals with the world of magnonics introducing space-time magnonic crystals and present an exceptional case of nonlinear wave physics in a comparatively large structure.** Thus, the ***general objective*** of this project is the analysis of spin wave dynamics (i) in magnetization textures that are periodical in space, and (ii) ultimately, in a new class of magnetization textures that are periodical both in space and time. **The main research** hypothesis is based on the assumption regarding a unique potential of nonuniform magnetization textures, especially those exhibiting space-time periodicity, as a medium for SW propagation.

This project will address theoretically few important issues in magnonics and physics. Although the project mainly bases on the theoretical and numerical investigation, the research will also be conducted in collaboration with experimental groups. We want to propose the structures ready for experimental validation or explain the results of measurements that have been already made. Especially, we will focus on magnetic systems based on mono- and multilayers with perpendicular magnetic anisotropy ferromagnetic/"heavy metal" (e.g., Co/Pt and Co/Pd), and also, in some cases, antisymmetric exchange interaction, so-called Dzyaloshinskii–Moriya interaction. Firstly, we will study the application of the transition regions between magnetization domains as ultra-narrow channels with unique properties for SWs propagation and a source of spin waves. Secondly, we will analyze how the properties of media influence the static and dynamic properties of periodic magnetization textures. Finally, we will use the acquired knowledge to analyze the condensation of periodical (in both space and time) magnetization textures, and then their features for SW propagation. This is a new kind of magnetization texture, up-to-date not considered in magnonics. In general, we will verify whether the STMCs form band structures at room temperature and that quasi-particles interact with these lattices like in regular crystals.

We believe that our research promises outstanding new opportunities not only in magnonics but also in fundamental research in non-linear wave physics. These investigations open the possibility for application of the magnonic devices to processing and routing of the high-frequency signals.