Quick progress that has been experienced by photonics during the past decade led to significant scientific and technical advances. They strongly affected society by changing its daily life and providing it with new instruments like global internet and solar energy. Demand in further development of internet infrastructure, dramatic reduction of the energy consumption, healthcare, safety and security applications, and photovoltaic generation is expected to be an engine of the extensive growth in the areas of photonics and nanotechnology in the next decade. It will strongly be affected by progress in available component platforms, which is expected to be connected with **metamaterials**, which are typically based on subwavelength resonators, and their planar version – **metasurfaces**. In turn, new efficient theoretical models and frameworks are highly demanded in order to understand what and how is achievable, and provide engineers with clear and efficient guidelines regarding design. Moreover, they should give recipes how to efficiently use the existing and commonly usable components, by proper combining them. **The general objective of this project is to develop the theoretical bases and design strategy for a perspective class of quasi-volumetric (thin) structures bounded by metasurfaces, which can be used in new multifunctional photonic and magnonic devices.** The research is planned to be conducted in several research directions, which include development of the theoretical bases and design strategy for (i) multifunctional operation, i.e., enabling two or more functionalities simultaneously in one device; (ii) control of propagation and transmission in the complex compact quasi-volumetric structures with the aid of metasurfaces, and (iii) tunability of the utilized metasurfaces using the externally controllable graphene. **New theoretical models and frameworks together with efficient design rules are expected to be the main output of this project.**

The planned theoretical studies take into account the fact that photonics and nanotechnology are the key enabling technologies. There are many functions like splitter, mirror, polarizer, lens, blazing grating, and diode, which are highly demanded for various applications in integrated photonics. Whether each of functions requires one separate device, or several functions and, thus, devices can be combined in one device will strongly affect the overall efficiency of future technology. The analogy with mobile communications might be illustrative. The first mobile terminals have had only a phone function, while the recent terminals enable several functions, e.g., Internet and GPS, in addition to the basic, i.e., phone function. What is also important is that the different functions are performed without interference, e.g., one can accept a phone call without switching off Internet. Similarly, one of the ideas to be implemented in the framework of this project is connected with combination of different functions in one device. For the purposes of the second illustration, let assume that we have two mobile terminals that have similar but not identical sets and/or characteristics of the operation modes, in which most of the used components are the same while the difference is achieved just by replacing one of the components. The said above illustrates well the idea of propagation/transmission controlled only by the boundary conditions, which is planned to be studied in the framework of this project. Indeed, we only change the boundary properties, or, in the other words, we replace one metasurface with another and expect the appearance of dramatic change in propagation / transmission characteristics. The third example from the area of mobile communications is aimed to illustrate how the operation mode can be tuned. It is very important if this can be done in a simple way, e.g., by simply touching a screen rather than by switching-off, reconfiguring / retuning, and switching-on again. This example illustrates the idea of tunability, which is planned to be realized in the framework of this project with the aid of graphene, a one-atom thick graphite. The choice of graphene was stimulated by the recent studies that demonstrate an unprecedented potential of this material. At the same time, the scenarios and regimes with enhanced selectivity to the externally controlled characteristics of graphene are expected to be not yet found. Hopefully, this can be done during the work on this project.

For the functions connected with a specific spatial distribution of the field (i.e., beaming, focusing), the idea will be considered how to find such boundary conditions and the corresponding metasurfaces that the desired characteristics can be achieved without a careful selection of the (quasi-) volumetric components. It will be implemented by modifying the widely used Transformational Optics approach in such a manner that the unknown parameter distribution to be found is only related to the external boundaries but not to the internal (i.e., quasi-volumetric) components. Using the above presented analogy once more, it is expected that only one component of a complex structure can be carefully chosen, in order to obtain a desired operation regime. The target frequency range extends from terahertz to infrared frequencies. Alongside the metasurfaces, photonic crystal slabs and layered metamaterials will be among the main building blocks of the complex quasi-volumetric structures to be studied. Once the theoretical bases are developed for the selected main directions, the acquired knowledge will be transferred to the area of magnonics and related microwave applications. The planned studies will utilize the classical theory of electromagnetic waves and optics, (semi-) analytical models, and recent advances in the related areas. The resulting framework should be based on the modified scattering matrix formalism and a set of (semi-) analytical formulas. Numerical simulations will be performed by using commercial software and self-made codes. **The obtained results are expected to open a route to new multifunctional devices controlled with the aid of metasurfaces.**