Elastic metamaterials are one of the most rapidly developing field of (structural) acoustics, due to their extraordinary properties and wave-manipulating characteristics. They exhibit many important dynamic properties, in particular bang gaps – ranges of frequency in which waves are strongly attenuated, negative reflection coefficients – e.g. reflected wave might propagate back to the source, enabling acoustical invisibility, and much more. Recently, topological insulators (TI), first observed in quantum mechanics, were adopted to elastic waves. TIs allow waves to propagate along structure boundaries with strong attenuation in the bulk. Special about TIs is that they allow creating topological protected states which might be used for one way propagation of waves (i.e. transport energy in one direction only) as they prevent reflections on geometrical imperfections. First goal of the research is therefore analysis and development of TIs but for specific structures – continuous bounded (guided) media.

Next step of work is extending usage of TIs by providing tunable capabilities. That can be realized in two ways – passively or actively. Passive attempt make use of nonlinear materials. Embedding nonlinear elements into metamaterial might e.g. move bang gap frequency depending on wave amplitude. Active attempt use external mechanisms like running a fluid through the structure or exposing it to magnetic field. The aim is to modify TIs for continuous bounded media to allow tunability using each of presented approaches. It should be emphasized that the proposed research assumes realization of TI by two techniques. First is a microstructural arrangement – composing materials with different properties at micro level to change macroscopic properties of propagating waves. Second technique use meta-grating and meta-clusters. Meta-clusters are “cells” embedded into structure which change properties of wave depending on properties of clusters and position of a set of clusters (meta-grating).

The research plan assumes two major and inter-related tasks and a laboratory validation phase. At first, analysis and development of the aforementioned TIs using both attempts – microstructural, and using meta-gratings. Second step is analysis on nonlinear mechanisms using passive and active methods in order to provide structural tunability. Finally, the proposed setups will be manufactured via 3-D multiphase printing methods and dynamic properties of metamaterials will be validated. There are many methods used for wave propagation analysis which will be used in project. Some of them are partial wave techniques (PWT) and Greens function approach (GF). Nonlinear materials can be analyzed using harmonic balance methods (HBM) and perturbation-based techniques. For complex system and optimization, numerical method will be used. Also analysis of measured data require numerical signal processing algorithms. For experimental research excitation and sensing devices are required. Research assumes using of piezoelectric transducers and laser vibrometers.