The goal of this project is to understand the process of elastic waves focusing in nonlinear layered media containing discontinuities through numerical simulations and experimental testing. A good example of the considered media are laminated composites, frequently used in engineering applications ranging from aircraft industry to sporting goods. Layered structure of these materials is due to the lamination process, where multiple layers are put together to obtain the desired mechanical properties. Inhomogeneity of the material arises due to the presence of multiple phases in the material, i.e. the reinforcement, usually carbon or glass fibers, and the polymer matrix. These type of materials offer excellent design flexibility and mechanical properties, but due to their structure are inherently prone to debondings, that can arise at the manufacturing stage or during the use. Debondings are very dangerous not only because they impair the mechanical properties, but more importantly because they can lead to critical failures and in turn to the loss of money, human health or life. An exemplary picture of debondings present in layered materials, obtained with micro Computer Tomography (μCT), is shown in Figure 1.

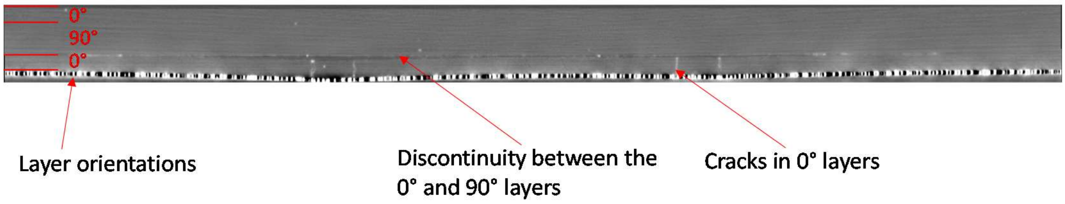

Figure 1. Exemplary image of debondings in an inhomogeneous layered material.

Discontinuities present in those materials are very difficult to detect, because they are usually generated in the volume of the material and are not visible on the surface. In engineering there are various materials testing techniques, including both destructive and nondestructive techniques, that could be used to probe the material. The most popular nondestructive techniques are based on ultrasonic waves propagation. However, even the well proven techniques used in metals are difficult to apply in the considered materials due to their inhomogeneous and layered structure.

One of the possible approaches to overcome these difficulties is to focus ultrasonic energy in both space and time to allow for the observation of a nonlinear response of the analyzed medium at the focal location. The main idea behind this approach is the fact that the presence of a discontinuity changes locally the mechanical response of a material from linear elastic to nonlinear elastic. This is in analogy to a linear spring where duplicating the tensile force results in duplication of the spring elongation. Because damage introduces nonlinearity to the material this relation will no longer hold and we can identify its presence and location.

The goal of this research project is therefore to understand the process of elastic waves focusing in inhomogeneous layered media and use it to find discontinuities in those media. To achieve this goal experimental testing will be performed with use of the state-of-the-art test equipment, and numerical simulations will be performed to better understand the physical principles and important parameters of this process. Eventually, **the knowledge resulting from the basic research proposed in this project will be the starting point for the development of nondestructive damage detection techniques that could be used in inhomogeneous layered media where the classical ultrasonic testing fails.**