Progress in physics is never linear but rather is reminiscent to an ascending staircase function with sudden jumps followed by long periods of a relatively slow but continuous growth. The sudden jumps (revolutions) happen roughly once or twice per century, e.g., classical mechanics 1700, theory of electromagnetism 1865, quantum mechanics 1900, general theory of relativity 1917. The revolutions in physics are triggered by inspired works of a small number of great scientists, such as Newton, Maxwell, Planck, Einstein, etc.. In fact, they create jobs for thousands of other scientists, who step in and do the necessary cleanup, clarifications, refinements, generalizations, finding mutual interconnections, implementations in engineering and transfer to the industry. These activities should not be however underestimated. In fact, without a congenial work of Oliver Heaviside who, twenty years later in 1885 put Maxwell's equations on solid footing, by reducing their number from 20 to 4 (quite a remarkable achievement, indeed), the development of our contemporary gadgets, such as cell phones or flat screen TVs, would be significantly delayed.

In the first decade of the 21st century we witnessed emergence of the metamaterial revolution in physics and engineering that was not so loudly heralded as former scientific revolutions, perhaps due to the fact that it occurred entirely in the realm of the classical physics (acoustics, optics, electromagnetism, mechanics, etc.). By the way, the name metamaterials is slightly misleading since metamaterials are very real materials and should not be confused with the Aristotelian notions of physics and metaphysics. In fact, metamaterials display a large number of new fascinating properties, which were totally unexpected or even considered as impossible. For example, in metamaterials we found negative mass density depending on the direction in space, negative elastic modulus of elasticity, negative Poisson ratio, invisibility (cloaking), super-focusing, super-resolution, reverse Doppler effect, transmission through ultra-narrow channels, perfect wave absorbers, negative coefficient of thermal expansion, static cloaking, deceleration of waves to a complete halt, etc.. Imagine that you can totally disappear from the scene like Harry Potter (cloaking), decelerate light waves to a complete standstill touching the rainbow (wave trapping) or help the princess from the Andersen's fairytale to hide the disturbing pea under a soft pad (static cloaking). Is it all magic? Not really, all these effects have been already achieved with metamaterials, functioning entirely within the frames of the existing laws of physics. It is however interesting to note that with the advent of metamaterials we realized that nature offered us only a small fraction of possible materials, since vast majority of the metamaterials developed up to date are man-made synthetic materials that cannot be found in nature, at all.

In this project we intend to exploit some peculiar properties of elastic metamaterials, i.e., their negative mass density and negative modulus of elasticity, to achieve giant sensitivities ($S_m^v \gg 500\ m^2/kg$) of Love wave sensors, working at low frequency range 1-3 MHz,. Again, there is nothing magic in the concept of negative mass density and negative modulus of elasticity. To understand these notions we have to break some common sense tacit assumptions about the mass density and modulus of elasticity. In fact, in everyday life we consider mass density as always positive since we tacitly assume that all components of the material vibrate in unison. If we break this assumption, a negative effective mass density means that an elastic material accelerates out of phase with respect to a harmonic excitation, force, (second Newton's law of dynamics).

The scientific objective of the project is to develop a theoretical foundations and establishing a mathematical model of the phenomenon of propagation of transverse surface Love waves in layered metamaterial media, and on this basis to develop a new Love wave sensor with extremely high sensitivity.

In our project we need to get an elastic metamaterial in which the wave front (phase velocity) of the wave propagates in one direction but the energy of the wave propagates exactly in the opposite direction. Is it really possible? Of course, it is if we can get an elastic metamaterial with a negative effective bulk modulus and negative effective mass density.

In our project we will combine two different elastic metamaterials. One of finite thickness (surface layer) with backward power flow propagation and second much thicker (substrate) with wave front and energy propagating forward. This will form a metamaterial waveguide for elastic surface waves of the Love type, discovered by the Victorian era scientist A. E. H. Love in 1911. If loaded on top with a viscoelastic liquid, such a metamaterial waveguide will constitute a sensor for measurements of mass loading and/or other viscoelastic properties of liquids. Since energy of the Love wave in the surface layer and in the substrate propagates in opposite directions it may happen that for some combinations of the material constants in the surface layer and substrate, as well as frequency of the Love wave, the overall power (energy) flow P_1 of the Love wave may cancel out, $P_1 \to 0$. Our preliminary analysis shows that in such waveguides, for which the overall power flow vanishes $P_1 \to 0$, the coefficient of sensitivity S_m^v of Love wave sensors should achieve extremely high values, in theory $S_m^v \to \infty$. The maximum sensitivity of the existing conventional Love wave sensors, working at very high frequency range 0.5-1.0 GHz, is now $S_m^v \sim 500\, m^2/kg$.

Achieving giant sensitivities ($S_m^v \gg 500\ m^2/kg$) of Love wave sensors, working at low frequencies 1-3 MHz, is of paramount importance in diverse fields of science, technology and health care system, e.g., in medicine, biology, chemistry, environmental monitoring, etc.. In fact, many serious diseases, such as hepatitis B, human immunodeficiency virus (HIV) antibodies or E. coli bacteria infection, require constant monitoring at patient home (Point of Care Testing). Similarly, in the environmental studies it is crucial to early detect tiny concentrations of harmful volatile substances, such CO, ammonia, pesticides, heavy metal particles, etc..