Description for the general public

The project concerns an original development and application of the plasmonics of finite electrolytes (soft-plasmonics) in analogy to the plasmonics of metallic nanostructures. The latter is with a great success currently applied to sub-diffraction photonics, e.g., to sub-diffraction manipulation of light by small metallic nanoparticles. Besides the formulation of the theory of ionic plasmon excitations and of ionic plasmon-polaritons, i.e., the wave type collective ionic surface plasmons hybridized with e-m wave and propagating along interface between conductor and dielectric, as observed in metallic structures, in the project it is planned the utilization of ionic plasmon-polaritons to qualitatively and quantitatively explain the still unclear so-called saltatory conduction in myelinated axons. i.e., in axons periodically covered with thick lipid sheath of the myelin. In these axons the electrical action potential seems to jump between consecutive so-called Ranvier nodes – small interruptions between ca. 100 micrometer long myelinated segments (hence the name ‘saltatory conduction’). This saltation results in large acceleration of the signal velocity up to 100-200 m/s, i.e., by two order larger than the upper limit for the ‘ordinary’ conduction in dendrites or in nonmyelinated axons (in the gray matter of the brain or spinal cord). The ‘ordinary’ conduction of signals takes place with small velocity of 1-3 m/s and has the diffusive ion-current character well described upon the classical cable theory (originated by William Thomson in XIX. century for description of electricity conduction in submarine oceanic telegraphic cable) and is limited by relatively poor Ohmic conductivity of ions in axon cytoplasm. Despite that the observation of the saltatory conduction dates to the middle of XX. century, its mechanism, certainly distinct from the one upon the cable theory, is still unclear and lacks a convincing theoretical description. Many attempts (mostly via improvement of the cable theory) failed and did not achieve agreement with key observations. In the present project we propose an original application of the mechanism of plasmon-polariton, i.e., of collective wave-type mode of surface ionic plasmons propagating along periodically modulated ion conductor to explain the saltatory conduction in myelinated axons. To this end we propose to develop the theory of plasmons in finite electrolytes confined by dielectric membrane in micrometer size scale typical to the cell organization level, utilizing an analogy to the nano-plasmonics in metals. Much larger mass of ions and lower their concentration in electrolytes in comparison to electrons in metals reduce the energy of plasmons and accommodate the typical system size to the scale of energy and size of bio-cells. Tentative assessments support strongly the feasibility of the project.

The project has an interdisciplinary character. Explanation of the role of myelinated sheath in saltatory conduction may contribute to better recognition of the severe disease – multiple sclerosis (MS), when even small losses in myelin layer result in lowering of the signal velocity and in the dysfunction of the motorics. Plasmon-polariton mechanism of the saltatory conduction offers quite distinct role for the myelin cover in comparison to the conventionally assumed opinion that it is only an electrical isolation. Plasmon-polariton mechanism of saltatory conduction would be also an important discovery in the field of electro-physiology of neuron signaling.